# Reclamation Research in the New World District 1994 Report of Search

FINAL REPORT FOR RESEARCH AGREEMENT
#INT-92705-RJVA
"Effect of Land Disturbances on Soil and Water Chemistry in the Intermountain West"
UTAH STATE UNIVERSITY
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# RECLAMATION RESEARCH IN THE NEW WORLD DISTRICT:

## 1994 REPORT OF RESEARCH

Submitted to:

Crown Butte Mines, Inc.
2501 Catlin St., Suite 201
Missoula, Montana 59801

01 June 1995

by:


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PLEASE NOTE

The data presented in this report were collected and analyzed by scientists of the U. S. Forest Service, Intermountain Research Station. Most of the data and information presented in this report have not yet been published (as of 01 June 1995). Therefore, we request that the reader respect the rights of the authors to publish first by not distributing these data without citing full and appropriate credit for the agency and scientists responsible for the information contained in this report. We suggest the following citation be used when referring to information in this report:

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## ACKNOWLEDGEMENTS

Pride in one's work is measured not just in how many plots are installed or how many data are collected that get published, but also in the people one gets to associate with while achieving it all. By that measure, we are very proud indeed for having the opportunity to know and work with some exceptional people.

We thank Noranda and Crown Butte Mines, Inc. for their willingness to work with us, and for funding assistance over the last several years which made much of this research possible. Their commitment to cleaning up the New World properties is exemplary, and we only wish others who claim concern would demonstrate a similar level of resolve to restoring these disturbances. In particular, we single out and thank Mr. Allan R. Kirk (formerly of Crown Butte Mines, Inc.) who assisted us in so many ways, including with funding, field work, with countless hours of commiseration over the untold problems of field reclamation, and the camaraderie that only comes from knowing first-hand the distress of unappreciated effort.

Restoring disturbed community-systems comes about through the efforts of numerous people, most of whom are rarely recognized adequately. However, we deeply appreciate the outstanding contributions made by such individuals as Ms. Angie Willis (who keeps us organized and focused, and always with a smile); Dr. Walter F. Mueggler (retired, but still can out-work and out-walk anybody else on the crew); Mr. Johnny Espinoza (Puerto Ordaz, Venezuela); Ms. Joan Brehm (USDA, Cochran Fellowship Program, Washington, D.C.); Mr. Patrick Williams (son of B. D. Williams, who can even maneuver an empty fishtailing pickup truck in the McLaren slime during summer snow storms like a true snow boarder), and Dr. Ezio Buselli (Lima, Peru), all of whom "passed the acid test" by surviving the humbling (some would say humiliating) experience of clipping, counting, and generally cavorting in countless plots under rain, snow, and occasional sun (but always on their knees!), digging soil and spoil samples, sloshing through the acid waters, and most importantly, collecting seeds of the general flora of Fisher Mountain and surrounding environs.

The assistance provided by so many other people is also impossible to adequately acknowledge, but they include (among many others): Sherm Sollid, Mary Lennon, John Logan, and Ron Gardner all of the Gallatin National Forest; Mike ("Alfred Hitchcock") Burnside, Norm Yogerst, Ray TeSoro, and Gene Colling, all of the Forest Service Regional Office (R-1), Missoula; and Mike ("I saw a trout *this* long in Fisher Creek") DaSilva, Montana Department of State Lands, who helped us free more than one truck from the mud.

Deep thanks go to Florence and Eddie Zundel of the High Country Motel, who claim they actually enjoy having us around. And to Bob and Patti Smith of Bearclaw Service and Cabins, who saw fit to trust us with their tools and some of their inventory during several dire episodes on the mountain, we extend our sincere thanks.

To our old friend and compatriot, Bob Johnston (deceased 1989), who first suggested I (R. Brown) work on the McLaren Mine way back in 1972, no measure of appreciation is sufficient.

# INTRODUCTION

During the summer of 1993 over 150 revegetation research plots were installed in the New World Mining District by Forest Service scientists and technicians with the cooperation of Crown Butte Mines, Inc. (e.g., see the FS 1993 Research Report, and the 1993 Research Proposal for a discussion of objectives, methods, and procedures followed). Research in 1994 was designed largely to assess and analyze the data from those plots, and when combined with research conducted in previous years, was intended to expand our knowledge of reclamation techniques and to better understand the impacts of reclamation on site restoration over time. Although many of the objectives of reclamation research conducted by the USFS-INT in the New World District have evolved over the last 23 years, the primary focus of developing techniques and methods for the establishment of native plant communities on severely disturbed acid mine spoil has remained intact.

Reclamation is viewed as the process of ameliorating chemical and physical conditions created by disturbance-causing agents (usually human, but also natural) that are considered limiting to some desired state. Thus, such conditions as accelerated rates of erosion, heavy metal-laden (and other) sediment transport, deteriorated water quality, and loss of site productivity can all be considered undesirable states requiring remediation and amelioration. Processes of remediation and amelioration may include activities such as land shaping and earth moving activities, drainage controls, surface treatments such as revegetation to minimize erosion and sediment movement, engineering structures, and others. Although effective in at least the short-term, these practices alone may not always be permanent and lead to the reestablishment of a natural *system* consistent with the vagaries and vacillations of the natural environment. Therefore, implementing techniques of *ecological restoration* are required, which is the process of reestablishing the natural community-system of an area consistent with the spontaneous processes of succession and ecosystem evolution. It is the objective of ecological restoration to restore, or reinstate, the same type of community system that existed prior to disturbance. Emphasis is given the words "..same *type* of community-system..." because we know with certainty that climatic shifts and environmental alterations occurring over the decades are constantly altering the forces driving such processes as succession, invasion, and soil genesis that ultimately lead to ecosystems as we see them today. As a result, reestablishing the same exact and identical community system that used to exist on an area is virtually impossible.

In our view, the processes of both reclamation and restoration are absolutely required to achieve the desired state of reestablishing natural community-systems on severely disturbed sites. In recent years our objectives have thus evolved to include the development of ecological restoration and reclamation techniques. As a result, the major hypotheses being tested by this research program include:

1. natural succession can be initiated and accelerated on severe acid mine spoil disturbances using aggressive reclamation-restoration treatments;
2. the plant communities established using these procedures will ultimately assume a natural successional trajectory leading to soil genesis, nutrient cycling, and the definitive reestablishment of self-sustaining natural community systems that are

evolutionarily consistent with the surrounding native ecosystem:

3. the reestablishment of active successional development will lead to a quantitative decline in acid production by pyrite-bearing spoils, with the ultimate improvement in quality of natural waters within impacted watersheds.

Although unsupported by quantitative data, the mine spoils presently visible in the New World area may resemble surface conditions that characterized the entire watershed in the Pleistocene following glacial retreat. It is probable that the geologic material comprising present-day mine spoils was generally exposed over much of the Fisher Mtn. area following glaciation. Present evidence in the area suggests that acid rock drainage was likely prevalent in most of the watersheds of the New World District throughout the period (including the present), and that perhaps Fisher and Daisy creeks may have transported large quantities of acidic waters and sediment. Simultaneous with glacial retreat, and continuing throughout the period to the present, it is likely that plant propagules of various species moved into these watersheds following a variety of migration pathways, including transport by wind, birds, mammals, insects, and other vectors. Further, presumably only a limited number of species were physiologically adapted to the severe environmental conditions then prevailing in the area. As isolated pockets of floristically-poor stands of vegetation became established, and as these developed into localized communities, soil genesis and nutrient cycling led to the eventual formation of more suitable habitats for greater numbers of species and plant lifeforms. As richer floristic communities developed, and as soil formation began to cover larger areas of exposed geologic material, acid formation resulting from the exposure of iron pyrites to oxygen and water may have declined significantly over time as the surface geologic material became sealed by the developing soil and vegetation. The native vegetation and soils that characterize the overall area today are products of the same processes of succession that resulted in the gradual development and coalescence of the original isolated pockets of developing plant communities and associated soil. Current community-systems in the area appear to represent very young stages of development in ecosystem evolution, and it is suspected that the overwhelming natural deposits of pyrite near the surface have continued to generate significant quantities of acidity, although perhaps in gradual decline in recent millennia. Thus, it is likely that Fisher, Daisy, and perhaps Miller creeks were never "pristine" in the traditional definition of the term (pure sources of water).

The evidence for these suppositions is overwhelmingly abundant throughout the Fisher Mtn. complex, and the interpretation of this evidence is critically central to developing successful reclamation and ecosystem restoration treatments for the severe disturbances resulting from human activity in the area. For example, the aggressive colonization behavior of *Carex paysonis* on acid mine spoils is evident at the McLaren Mine, Como Pit, Glengarry Adit, numerous old spoil piles scattered on surrounding slopes, and along miles of various road cuts and fills. This species has a rhizomatous growth habit that results in considerable lateral surface spread of vegetative structures with dense aggressive rooting habits. Preliminary research data suggest that this species is highly acid- and heavy metal- tolerant, and that it modifies spoil properties significantly over time. Characteristically, interior portions of the circular architecture of *Carex paysonis* "pads" experience progressive mortality with increasing age and

"pad" size, leaving behind circular-shaped zones of organic debris rich in nutrients over a layer of "modified" mine spoil material. The "dead centers" of these pads become prime colonization sites for other less acid tolerant species over time, and small isolated patch-communities thus become established on acid mine spoil sites. Learning how to actively mimic the role of this species in initiating succession is critical to successful reclamation and restoration of these lands.

Evidence supporting long-term acid rock drainage in the watersheds of the New World District is widespread below the McLaren Mine where present-day seeps of acidic waters are visible within old *Carex paysonis* communities. It appears that these seeps have been active for much longer periods of time than human activity in the area because the development of *Carex paysonis* "pads" around these seeps is virtually static; these is no evidence of periodic fluctuation in pad out-growth or fringe mortality, indicating that a somewhat dynamic equilibrium has been established between the growth of the pads and the margin of the seeps. Our experience with *Carex paysonis* pads suggests that pad expansion occurs rapidly during favorable periods (as much as several cm/yr on mine spoil), and that remnants of dead pads are persistent for decades following mortality (as viewed in the "dead-tree" zone below the south end of the McLaren Mine). Thus, it is evident that the apparent equilibrium between *Carex paysonis* pad growth and acid seep perimeters has been stable for many decades. The extensive development of solid *Carex paysonis* communities across the slopes and near these seeps, and hence the equilibrium that exists between them, have obviously been intact for time periods much longer than the presence of European society in North America.

Quite apart from the controversy and high level of public visibility of the area, the reclamation research conducted on the New World sites represents the longest continuously monitored high elevation ecological restoration research in North America, and has become an important source of reference information for the reclamation and restoration of disturbed lands at high elevations World-wide. It is among our highest priorities that the scientific integrity and credibility of this research be protected and enhanced, and to protect the public interest by making the results of this work available to all individuals, regardless of affiliation.

This report summarizes the reclamation-restoration research activity and data collected during the field season of 1994 by USDA Forest Service scientists of Research Work Unit 4301, Intermountain Research Station (Brown and Chambers 1990; Brown and Johnston 1976; 1978, 1979, 1980, 1988; Brown et al. 1978, 1984; Johnston et al. 1975; Haggas et al. 1987).

## SUMMARY OF PLOT INSTALLATION AND LOCATIONS

Reclamation and ecological restoration research plots have been installed in numerous locations throughout the New World District since 1972 by FS scientists, some of which are no longer active or have been destroyed, but many of which are still being monitored. Figure 1 is a map of the remaining active research plots in the area, and illustrates the locations and dates of installation for each active set of plots. The basic objectives for all these plots were similar: to develop techniques and methods for successfully revegetating and reestablishing a native protective plant cover on exposed acid mine spoils at high elevations. Specific objectives and hypotheses have evolved over the last 20+ years of research in the area, but the focus of the overall program has remained essentially the same.

NEW WORLD RECLAMATION-RESTORATION PLOT LOCATIONS

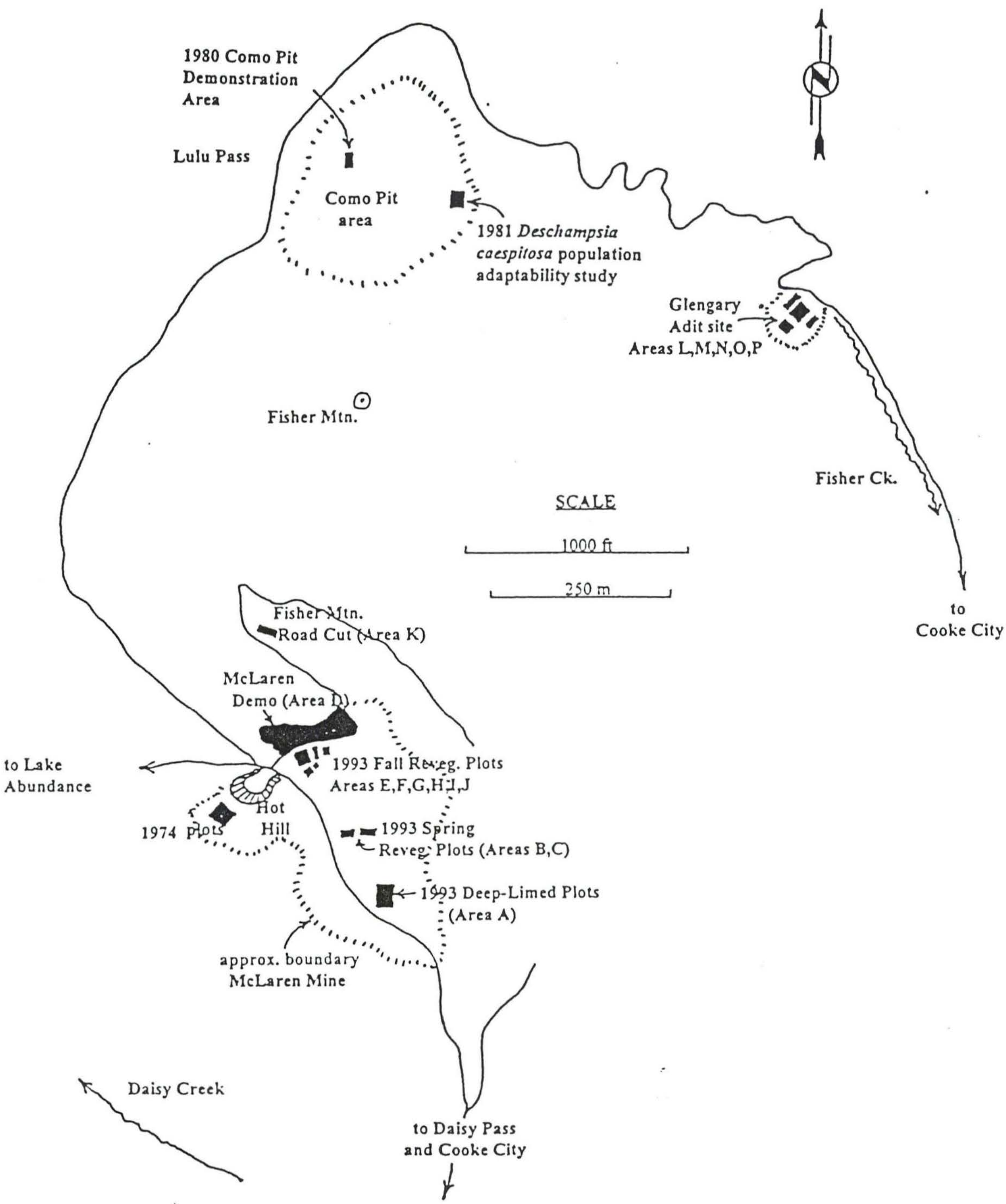



Figure 1. Map of a portion of the New World Mining District showing locations of reclamation-restoration research plots installed and monitored by USDA Forest Service scientists between 1972 and 1994.

The most recent plot-sets were installed in 1993 with the cooperation of Crown Butte Mines, Inc. The objectives of the revegetation-restoration research undertaken during the field season of 1993 (see USFS 1993 Report) included determining the quantitative effects of the following variables on the establishment of a protective plant cover composed of native species on acid mine spoils and other severely disturbed lands :

1. Spring vs. fall season of revegetation installation.
2. Effectiveness of different surface restoration treatments on trapping seeds of native plant species ("seed rain").
3. Relative efficiency of native "seed rain" for establishing a protective plant cover composed of native species compared with direct seeding of native species.
4. Relative effects of surface mulching vs no mulching on the establishment of a native vegetative cover.
5. Relative effects of incorporating organic matter into the surface of disturbed sites vs no organic matter on the establishment of a native vegetative cover.
6. Effects of liming vs no liming, and the effects of depth of liming, on the establishment of a native vegetative cover.
7. Effects of enhanced phosphorus fertilization on plant responses and establishment on acid mine spoils.
8. Relative effects of enhanced rates of organic matter incorporation on the establishment of a native vegetative cover.
9. Relative performance differences among the principle native plant species most important in revegetation of high elevation acid mine spoils.
10. Retreatment of selected plots within the 1976 McLaren Demonstration Area with fertilizer, limestone, and fertilizer+limestone to determine the effects of periodic re-applications of amendments on long-term vegetation establishment.

The locations of the various plots installed on the McLaren and Glengarry sites in 1993, together with the locations of older restoration research sites, is illustrated in the map reproduced in Figure 1. Detailed maps of plot layout configurations and treatment applications for each plot-set are reproduced in Appendix 1, and detailed tables of amendment application rates are reproduced in Appendix 2 (also see USFS 1993 Report).

## 1994 ACCOMPLISHMENTS

The following reclamation and restoration research was accomplished during the field season of 1994:

1. Assessment of revegetation plots for percent cover, species composition, and above-ground biomass for all revegetation plots installed in 1993, and the McLaren Mine Demonstration Area.
2. Installation of *Carex paysonis* transplant plots on the Glengarry Adit spoils transplant plots and the McLaren Mine spoil transplant plots.

3. Re-fertilization of 2/3 of the area of the 1993 revegetation plots at the Glengarry Adit site, spring and fall seeded plots, and on the McLaren Mine spring and fall seeded plots, and the McLaren Mine deep-limed plots.
4. Treated Fisher Creek tributary (Sheep Mtn. tributary) with pelletized limestone to determine effect on metal loading.
5. Pulsed Fisher Creek with sodium hydroxide to determine effect on pH and metal loading.
6. Sampled water quality in Fisher and Daisy creeks.
7. Sampled soil surface erosion on all restoration plots and adjacent reference areas with the rillmeter.
8. Re-assessed the Miller Creek native plant seed garden, and re-treated with fertilizer.
9. Assessed the restoration retreatment plots within the 1976 McLaren Demonstration Area.
10. Collected and analyzed soil samples from within the McLaren Mine Demonstration Area, and compared these with soil samples from adjacent native undisturbed reference communities.

## METHODS AND PROCEDURES

The large number of reclamation research sites in the New World area was, by 1994, becoming confusing and difficult to sort out. Therefore, we assigned a letter designation or code to each set of plots to help organize the various data sets and photographic records being maintained for each site. Table 1 is a list of research plots and associated letter designations, and summarizes these codes and the locations and installation dates of all research study areas currently active in the New World District.

The following methods and procedures were employed for each of the outlined activities and achievements during the 1994 field season:

### 1. Assess all revegetation-restoration plots.

Assessments of plant growth and development were made in all revegetation-restoration plots installed in 1993 together with those established within the 1976 McLaren Mine Demonstration Area, and within the native undisturbed reference area plant community adjacent to the Demonstration Area.

Percent vegetative cover is determined by taking vertical photographs of 3 quadrats, each 0.25 $m^2$, on each revegetation plot (upper, mid, and lower 1/3 of each plot). The permanent location of each quadrat frame is established by staking. Vertical photographs (35 mm slides, 25 ASA, with a flash) are taken of each quadrat, labeled by both hand and with a data-record-back on the camera. Cover is assessed by projecting the photographic image onto a 100-point grid and counting the number of "hits" in each of the following categories: live plant, litter (dead plant material or mulch), cryptogam (moss, lichen, etc.), rock, and bare ground. The net results yield percent cover by each category, including the residual bare ground component.

**Table 1:** Letter codes, plot locations, and installation dates of each active reclamation-restoration research site in the New World District.

| Letter Code | Plot Location | Total No. of Plots | Date of Establishment |
|---|---|---|---|
| | McLaren Mine | | |
| A | Deep-lime plots | 6 | Sept. 1993 |
| B | Spring-seeded plots | 12 | July 1993 |
| C | Spring unseeded plots | 12 | July 1993 |
| D | Demonstration Area | 1 | Sept. 1976 |
| E | Fall-seeded plots | 12 | Sept. 1993 |
| F | Fall-unseeded plots | 12 | Sept. 1993 |
| G | Single-species plots | 6 | Sept. 1993 |
| H | Transplant plots | 4 | Sept. 1994 |
| I | Phosphorus plots | 12 | Sept. 1993 |
| J | Organic Matter plots | 4 | Sept. 1993 |
| | Fisher Mountain Roadcut | | |
| K | Fall seeded and unseeded plots | 12 | Sept. 1993 |
| | Glengarry Adit | | |
| L | Spring-seeded plots | 12 | July 1993 |
| M | Fall-seeded plots | 12 | Sept. 1993 |
| N | Fall-unseeded plots | 12 | Sept. 1993 |
| O | Single-species plots | 6 | Sept. 1993 |
| P | Transplant plots | 4 | Sept. 1994 |
| | Native Reference Areas | | |
| Q | McLaren reference (above Demo.) | 0 | Sept. 1977 |
| R | McLaren reference (below Demo) | 0 | July 1995 |
| | Older Research Sites | | |
| X | "72" plots below Hot Hill | 72 | Sept. 1974 |
| Y | Como Pit Demonstration Area | 1 | Sept. 1980 |
| Z | Deca Adaptability Plots (Como Pit) | 54 | Sept. 1981 |

Above-ground species biomass (or standing-crop) is collected by clipping the plants at ground-level within each quadrat frame with scissors. Biomass is determined by collecting all vegetation in labeled and sealed paper bags, over-drying at 80°C in the laboratory, followed by

weighing. Clipped quadrats were established separately from the permanent cover quadrats above to avoid or minimize disturbance. In 1994, during the first growing season of the 1993 plots, clipping was restricted to the total vegetation within each quadrat frame in each area and related to plant density (number per unit area). Because identification of individual species during the first growing season following seed germination is highly subjective and susceptible to error, harvesting by species at this early stage of development was not attempted. Instead, total vegetative biomass was determined by harvesting all vegetation within each quadrat frame. Harvesting by species will be performed beginning in 1995.

Biomass by species was analyzed on all older plots of the McLaren Demonstration Area and the adjacent native reference area using 0.5 $m^2$ quadrats in 1994.

Soil samples in the 0-15 cm depth range were collected from all plots and assessed for pH in the laboratory during the winter 1994-95.

**2. Install *Carex paysonis* transplant plots on the Glengarry Adit spoils transplant plots and the McLaren Mine spoil transplant plots.**

Pads of *Carex paysonis* were collected from the Como Pit area by employees of Crown Butte Mines in late fall, 1993, and stockpiled on the mine. The pads were allowed to over-winter, and showed little mortality by the summer of 1994. Two sets of transplant plots were established in 1993 using these plants: 1) on the Glengarry Adit spoil pile, and 2) on the McLaren Mine spoils near the fall seeded and unseeded plots (see Figure 1 for locations of plots, and Appendix 1 for specific plot maps). Both sites had 4 different transplant plots established, each plot 5m x 5m (25$m^2$) in size. The following amendments were applied to each plot in 1993:

plot 1: lime + fertilizer
plot 2: lime + no fertilizer
plot 3: no lime + fertilizer
plot 4: no lime + no fertilizer

Within each plot a total of 5 *Carex* pads were planted (e.g., center, and four surrounding pads) in September 1994. Depressions matching the pad size and root length were dug, the spoil material saved and then packed around the root systems. Each pad was watered after planting to optimize root contact with the soil and to minimize temporal plant water deficits. The exact diameters in two directions were recorded and marked with chaining pins for each pad for future assessment of growth rate and development as affected by treatment. Vertical photographs of each pad were also taken following planting in 1994, and will continue each year afterward, to assess cover, growth rate, mortality within the pad, and colonization by other species.

Pads used were selected carefully for uniformity of size and shape, healthy appearance, and well-developed rooting habits. A total of 20 pads were planted on each site (e.g., 5 per plot x 4 plots x 2 locations = 40 total pads).

3. **Re-fertilize the lower 2/3 of the plot area of the 1993 revegetation plots at the Glengarry Adit spring and fall seeded plots, the McLaren Mine spring and fall seeded plots, and the McLaren Mine deep-limed plots.**

Re-fertilization schedules for high-elevation revegetation installations remain one of the more controversial issues in assessing potential success of revegetation and restoration efforts. We subdivided the plots installed in 1993 into thirds (1/3), and applied the following re-fertilization treatments: upper 1/3 fertilized during installation only (1993); middle 1/3 re-fertilized once in the second growing season (1994); lower 1/3 re-fertilized twice, during the first and second growing seasons (1994 and 1995). Plot configurations and layout schemes are illustrated in Appendix 1, and application specifications for each amendment are documented in Appendix 2. In addition to all spring and fall seeded and unseeded plots, all the single-species plots at both Glengarry Adit and McLaren Mine plots were also re-fertilized.

The plot design in 1993 shows the plots to be 6.5' x 80' in size (Appendix 1: sites B, C, E, F, L, M, N). However, during installation we decided to incorporate organic matter (peat moss) into the lower one-half of each plot to test the hypothesis that organic matter will enhance nutrient and water holding characteristics and improve metal complexing. Hence, we divided the original plots into 2 halves, each 6.5' x 40'. These plots were divided again, into 3 subplots, each 6.5' x 13.3' in size (86.45 sq. ft.) to test the additional hypothesis that re-fertilization enhances plant community developed as a function of re-fertilization frequency..

All re-fertilization was accomplished with 31-4-4 (N-P-K) at the equivalent rate of 100 lbs. N/acre. Nitrogen is the most limiting nutrient on these areas, but P and K are largely adequate following the initial applications of 16-16-16 and triple-superphosphate. We used 200 lbs P/acre in 1993, and because P is relatively immobile, we believe it remains adequate for plant growth based on yearly soil analyses data.

4. **Treated Fisher Creek tributaries (Sheep Mtn. tributary and others) with pelletized limestone to determine effect on metal loading.**

Crushed, pelletized limestone was applied to the stream bottom of the Sheep Mountain tributary and other smaller tributaries along the upper reaches of Fisher Creek to raise the alkalinity of the tributary waters. Approximately 300 lbs. total limestone was used. This is expected to adsorb Cu onto hydrous $Fe^{3+}$ oxides on the streambed rocks of Fisher Creek. It is also expected that this will help confine the zone affected by acid mine drainage to the upstream portion of the drainage, and result in better protection of downstream waters by lengthening the buffer zone between areas affected by AMD and more "pristine" stream reaches. All data collection will begin in 1995.

Although considerable criticism by various groups was heaped on FS scientists and Crown Butte Mines, Inc. employees for conducting this study, we feel such criticism is unwarranted. One complaint suggests that limestone is an inappropriate substance in such waters, and that its use may create an unfavorable and perhaps unnatural chemical environment that might "forever alter the surface water and groundwater baseline at the mine site" (quoted from a letter dated 9/7/94 from Peter Aengst of GYC to Dave Garber, Forest Supervisor of the

Gallatin NF). Such expressions of concern, although well within the rights of attentive citizens, suggest gross unfamiliarity with, and knowledge of, basic natural processes. Limestone is a completely natural substance, is totally indigenous to the local area, and comes in contact naturally with virtually every stream in the Beartooth Mtns. (to say nothing of virtually every stream in North America!) at one or more points along the stream's course. In Fisher Creek, unfortunately, natural limestone outcrops are absent near the upper stream reaches, and unlike Daisy and Miller creeks, limestone is contacted only along the lower reaches of Fisher Creek. This apparent geologic anomaly appears to propagate the degradation in water quality in the upper reaches of the stream due to contaminants discharging from the Glengarry Adit. Artificial additions of pelletized limestone in no way violates the natural order of things, and if anything, is intended to result in a significant improvement in water quality along the upper and lower reaches of Fisher Creek (e.g., see Simonin 1988 for a discussion about the value of liming contaminated waters). Crown Butte Mines, Inc. funds were not used for this study.

5. **Pulsed Fisher Creek with sodium hydroxide to determine effect on pH and metal loading.**

The pH adjustment study using sodium hydroxide (or sodium carbonate) that was first performed in August, 1992 (Amacher et al. 1993) was repeated in Fisher Creek in 1994. This study was repeated to verify results observed in 1992, and because the target pH in 1992 was exceeded. This study will help determine optimum rates and concentrations of treatment required to achieve desired water pH. Crown Butte Mines funds were not used for this study.

6. **Sample water quality in Fisher and Daisy creeks.**

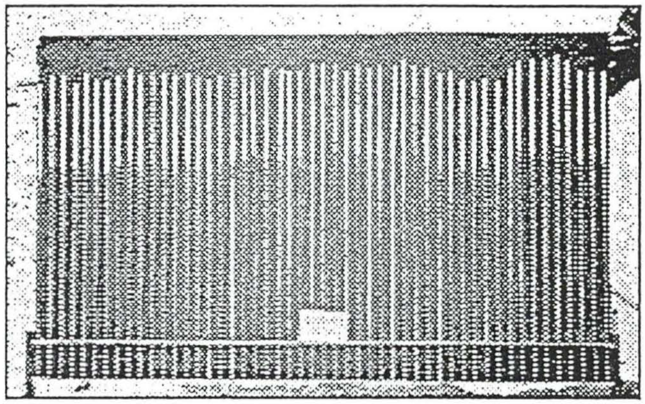
Water sampling at various stations along both Daisy and Fisher creeks were continued, together with measurements of discharge. Although this research by USFS scientists has traditionally not been funded by Crown Butte Mines, Inc., and results and data are not normally reported in these reports, this work and that in 4 and 5 above is being mentioned here simply to illustrate continuity of the over-all research program in the New World District (contact M. Amacher with specific questions regarding water quality research).

7. **Sample soil surface erosion on all plots and adjacent reference areas with the rillmeter.**

Rillmeter measurements of the soil surface were made on all the revegetation plots installed in 1993, together with adjacent native reference areas, as a baseline for future observations of surface erosion. Permanent plot stakes were established and recorded on each revegetation plot in 1993 so that the same surface can be re-sampled each year. These observations were continued in 1994 in order to determine the effectiveness of the various treatments applied for minimizing surface erosion on the various sites being studied. These data combined with those in **1.** above (**Assess revegetation plots...**) will provide a more rigorous assessment of revegetation and reclamation success (or failure!) than is traditionally made in

revegetation research because treatments and amendments can now be evaluated in terms of both vegetation characteristics and effectiveness for minimizing soil surface erosion. These data are expected to provide leading-edge data for assessment of revegetation potential in the New World District, and should lend considerable credibility to our assessment of future results.

A rillmeter is a device used to measure erosion and rill formation on pre-established sites. Sites are established by driving rebar stakes or similar type rods approximately 2 feet into the ground at one edge of the plot, and another rebar is located 5.0 feet from the first stake perpendicular to the slope. One leg of the rillmeter is placed over the first rebar stake, which becomes a permanent reference point. The other leg, which contains a leveling device, is placed next to the second rebar stake. The leveling leg is used to level the rillmeter perpendicular to the slope and a second level is used to level the instrument horizontally. After the meter is level, a series of 50 pins of equal length located uniformly over the 5 foot width of the rillmeter are adjusted so they just touch and conform to the soil surface. The tops of the pins, when viewed against the surface background board of the rillmeter form an image of the soil surface which can then be photographed. The area above the top of the pins across the background board can then be computed by image analyses to determine changes in surface characteristics such as rill formation or surface roughness. Over time, a series a photographs are collected and used to characterize erosion, rill formation, and surface roughness.



A total of 90 permanent rillmeter plots were established during the 1993 field season. They were located on each of the spring and fall seeded and unseeded plots at the McLaren Mine and Glengarry Adit sites, and on 3 native reference plots at both locations. In addition, during the 1994 field season an additional 4 plots were established on the McLaren Demonstration Area. Photographs taken during the 1993 field season are used as the baseline data against which each subsequent years' photographs are compared using image analysis software.

**8. Re-assess the Miller Creek native plant seed garden, and re-treat with fertilizer.**

The Miller Creek native plant seed garden was assessed for survival and growth of the various species that were planted in Sept. 1990. In addition, the garden was re-fertilized with 16-16-16 at the equivalent rate of 100 lbs N/acre. No attempt was made to remove invading plants from the garden area because, after examining the site, we felt that natural succession should not be deflected. The Miller Creek garden site is probably not the best location for a native plant seed garden, and in our opinion, the meadow should be allowed to return to its natural state through succession. Better sites for seed gardens of plant species to be used in reclamation of mine spoils would include sites directly on the McLaren Mine or Como Pit areas.

These sites would be better-suited as seed garden locations because competition from invading plants would be dramatically reduced, and natural selection would sort (or edit) out undesirable species and genotypes.

**9. Assess the retreated plots within the McLaren Mine Demonstration Area.**

A total of 12 plots, each 10 ft. wide by about 110 ft. long, were established within the McLaren Mine Demonstration Area in 1993 to test the hypothesis that retreatment of old reclamation sites can enhance and accelerate the successional development of plant communities. Four treatments (control, limestone, fertilizer, and limestone + fertilizer) were applied, with 3 replications each, randomly within the plot area in September, 1993. These plots were assessed for plant cover, biomass by species, and lifeform and species diversity in three 0.5 $m^2$ quadrat frames within each of the 12 plots in 1994. The same techniques were used as described in **1. Assess all revegetation-restoration plots .**, above.

**10. Collect and analyze soil samples within the McLaren Mine Demonstration Area, and compare with native reference soils.**

Soil genesis is occurring on various older restoration plot areas at a much more rapid pace than expected, and in 1994 we noted dramatic organic staining and soil development throughout the entire seeded portion of the Demonstration Area. Therefore, we sampled the developing soils by horizon at 6 different locations across the Demonstration Area. Samples were similarly collected from the adjacent reference area up-slope from the Demonstration Area. These soils, together with comparative samples of untreated mine spoil, were analyzed at Utah State University Soil, Plant and Water Analysis Laboratory, and the results are described below.

## RESULTS

### 1. Assessment of Revegetation-Restoration Research Plots

All revegetation-restoration plots were assessed in August 1994, including the newest plots established in 1993, and some of the older plots installed prior to 1993. Data summaries are discussed below by plot type and location. See Figure 1 and Table 1 for locations and letter designation codes, Appendix 1 for individual plot layout and orientation information, and Appendix 2 for specifications for amendment applications used. The majority of data discussed in this report represents first-year results from the revegetation-restoration plots installed in 1993; older results were observed only on the McLaren Mine Demonstration Area, and will be discussed separately.

Plant cover data are not reported here because the 1994 cover photos were over-exposed. It was impossible to quantitatively measure cover from the poor quality of the photos this year, so these data will be collected again in 1995.

## McLAREN MINE PLOTS

Area "A": Deep-lime plots:

The deep-limed plots, located near the south end of the McLaren Mine, were installed in Sept. 1993, and included the following main treatments: 1) deep liming (hydrated lime to 2 ft. depth); 2) shallow liming (6 in. depth); (3) no lime applied; (4) incorporated organic matter (peat moss; see Appendix 2 for rates); and (5) no organic matter incorporated. The entire plot area was fertilized, seeded, and surface mulched with erosion blanket (see Appendix 1 and 2 for specifications used). Total plant biomass data were collected from each plot in the deep-limed plot complex, and are illustrated by treatment in Figure 2. The data show that biomass production of plants was greatest in deep-limed plots that also received incorporated organic matter, and was least in plots that were not limed. Without liming, the incorporation of organic matter had no effect on plant biomass, thus indicating that lime is essential for plant establishment, and growth and development on McLaren Mine spoils.

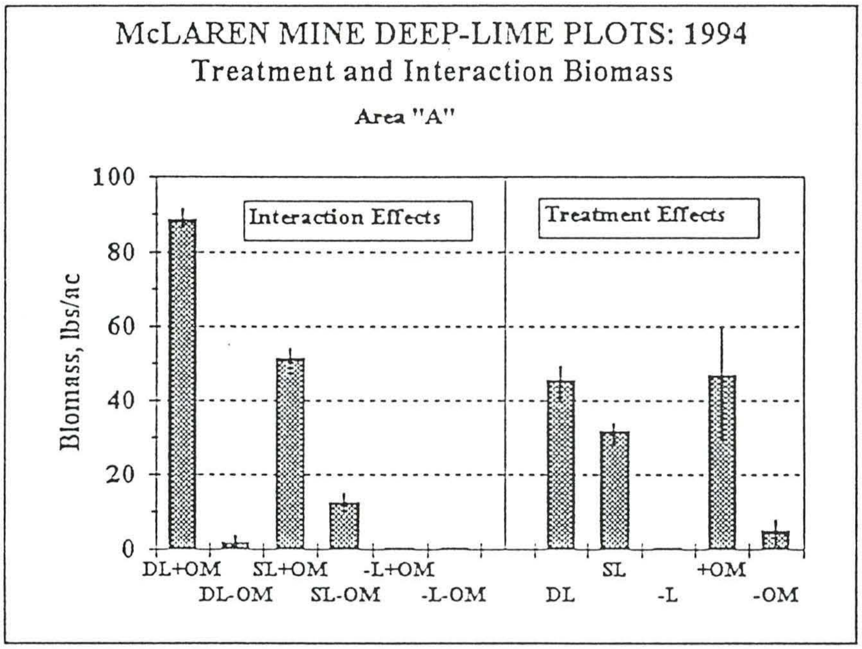



Figure 2. Plant biomass of McLaren Mine deep-lime plots (Area "A") in 1994 showing main treatment effects (right) and interaction effects (left) of treatments. Abbreviations include: DL deep lime; SL shallow lime; -L no lime; +OM incorporated organic matter; -OM no organic matter incorporated.

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Main treatment effects (right) show that both liming and organic matter incorporation have strong influences on plant biomass during the first growing season following plot installation. Similarly, interaction effects (left) illustrate these same influences when both

treatments are combined, but most significantly show that organic matter without liming is ineffective on this site during the first growing season.

Areas "B" and "C": Spring seeded and unseeded plots:

The McLaren spring seeded and unseeded plots were established in July 1993 on the McLaren Mine between the county road and the McLaren Pit on a west-facing exposure (see Figure 1). Both plot areas were limed at the rate of approximately 1.4 tons/ac (see Appendices 1 and 2), fertilized, seeded (Area "B") or not seeded (Area "C"), the lower-half of each plot was treated with incorporated peat moss organic matter at the rate of 5864 lbs/ac (Appendices 1 and 2), and then half the plots were mulched with erosion blanket in a random design. First growing season biomass data (Figure 3 and 4) show both interaction and main treatment effects, including mulching vs no mulching, organic matter vs no organic matter, and seeding vs no seeding.

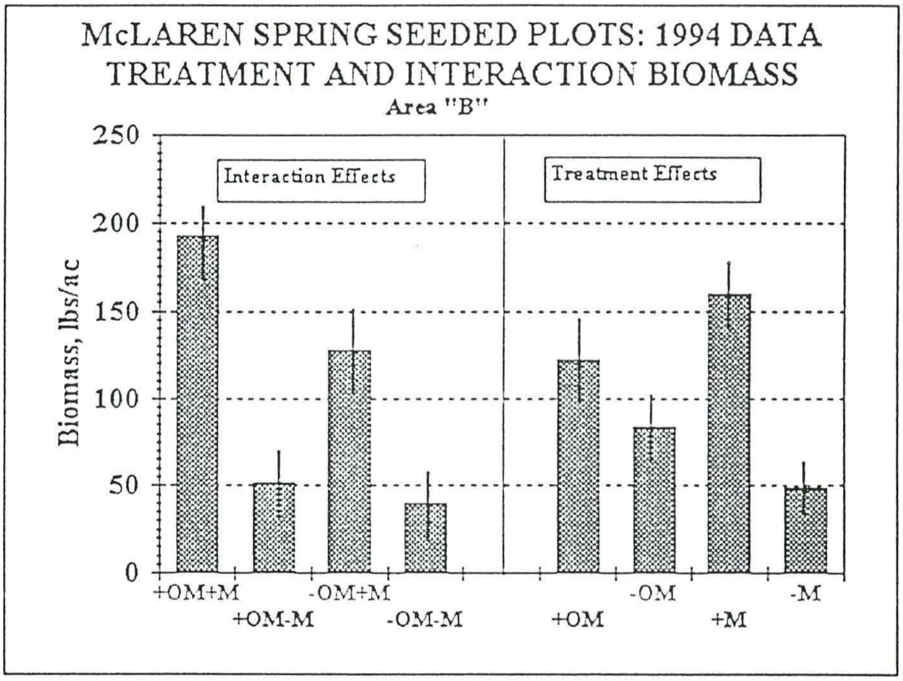


Figure 3: Plant biomass of McLaren Mine spring seeded plots (Area "B") in 1994 showing main treatment effects (right) and interaction effects (left) of treatments. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

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Data from the spring seeded plots (Figure 3) show that incorporating organic matter combined with surface mulching resulted in greater first-growing season biomass than other treatments. However, interaction effects data indicate that mulching had a greater effect on plant

biomass than organic matter incorporation alone, and this is supported by main treatment effect data (right). Organic matter incorporation without surface mulching resulted in similar biomass as treatments with neither organic matter or mulch added. Interestingly, these treatments resulted in a net dry weight biomass of over 100 lbs/ac during the first growing season, and illustrate the significance of both organic matter and mulching.

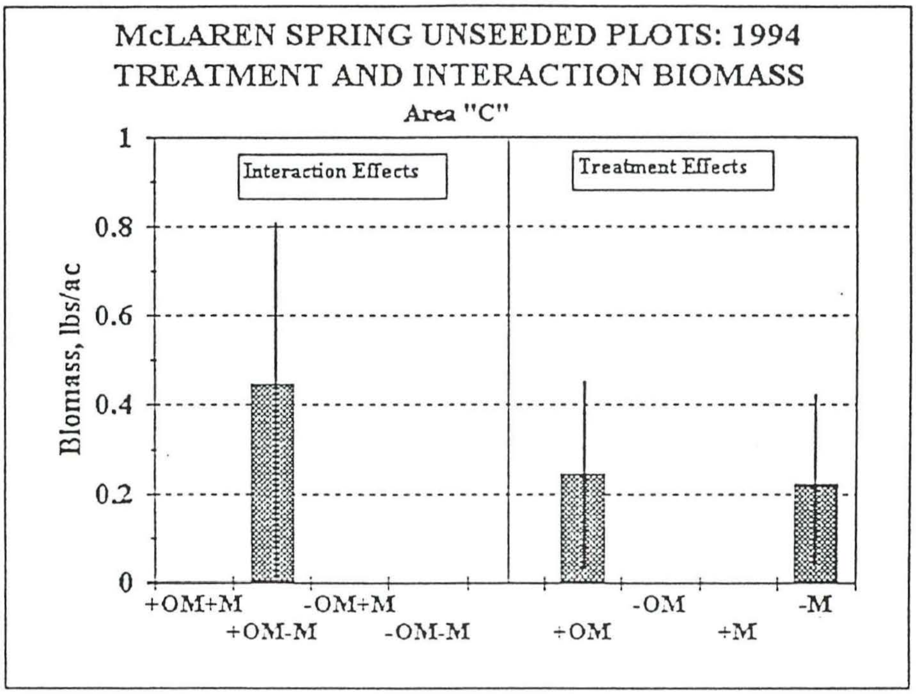


Figure 4: Plant biomass of McLaren Mine spring unseeded plots (Area "C") in 1994 showing main treatment effects (right) and interaction effects (left) of treatments. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

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Biomass in the unseeded plots (Figure 4) represents natural seed rain colonization and establishment during the fall of 1993 and spring of 1994, whereas biomass in the seeded plots represents development from both seeded plants and seed rain establishment. Natural seed rain contributed only about 1/250 the biomass during the first year that was produced on seeded plots (Figure 3, above), and suggests that natural seed rain is not always a reliable source of seeding for surface protection. It appears from these data that organic matter incorporation had a significantly greater effect on seed trapping (Figure 4) than did mulching. Although this is dramatically different from expected results, additional data may be required over time to sort out the relative roles played by these amendments. It is far too early in the development of these young plant communities to be definitive about the effects of any amendment and treatment

interactive effects on plant production.

Area "D": McLaren Mine Demonstration Area Retreated 1993 Plots:

A portion of the McLaren Mine Demonstration Area was set aside in 1993 and divided into 12 plots, each plot being 10' wide x about 110' long. In a randomized block design the following treatments were applied: control (no treatment); fertilizer; limestone, and limestone + fertilizer, each replicated three times. The intent in these plots was to determine the effects of re-treating old revegetation sites to stimulate and accelerate successional development of plant communities and soils within them. The data from the first year responses are summarized in Figure 5 (see Appendices 1 and 2 for plot maps and amendment application rates).

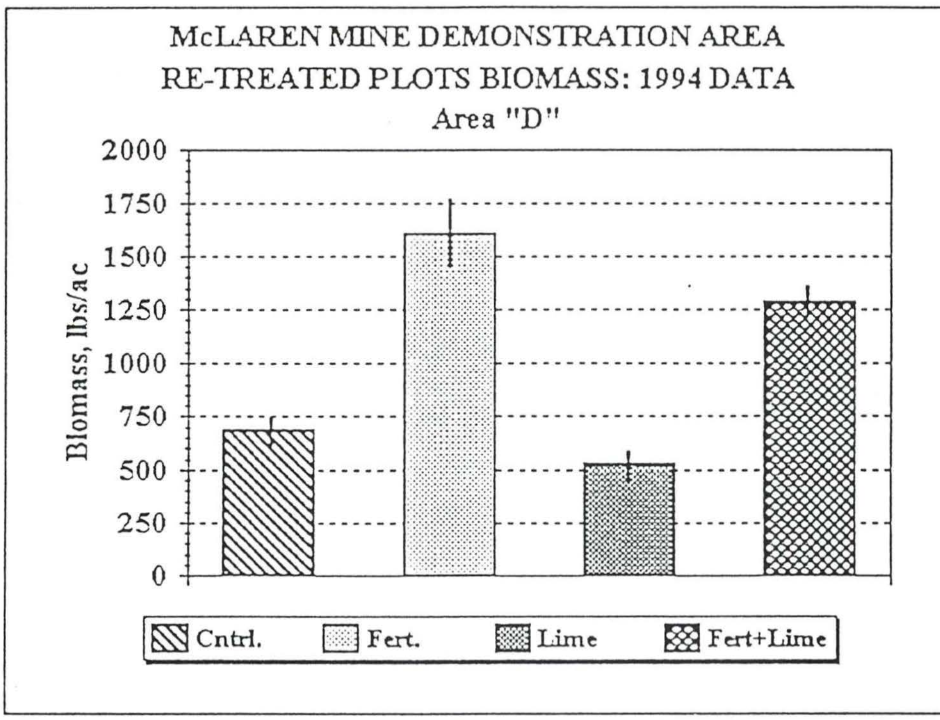


Figure 5 Plant biomass on McLaren Mine Demonstration Area retreated plots (Area "D") in 1994. Abbreviations include: cntrl.... control; fert.... fertilizer; lime....limestone (crushed pellets); fert.+lime....fertilizer and limestone.

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The retreated plots in the Demonstration Area show that after one full year following re-treatment, fertilizer had the greatest effect on total plant biomass. The response from crushed limestone alone did not differ significantly from the control, indicating that limestone pellets did not affect soil conditions during the first growing season. It is suspected that more time may be required for crushed limestone to have any detectable effect on plant responses. Applications of

fertilizer and crushed limestone together also significantly increased biomass over control levels, but it is apparent that most of that increase is due to the fertilizer. Based on these data, it is evident that more time is required to determine the long-term effects of re-liming old plots such as these using crushed limestone. However, increases in biomass from fertilizer applications are obvious; of far greater significance will be the long-term implications of the fertilizer. One major concern is that fertilizer favors grasses over forbs, and may have the effect of setting succession back by creating a solid grass sward on the site that prevents the forbs from establishing and developing due to enhanced competition. These plots will become increasingly interesting and important in future years for assessing the long-term effects of retreatment.

Areas "E" and "F": McLaren fall seeded and unseeded plots:

The McLaren Mine fall seeded and unseeded plots were installed using the same treatments as those used in the spring seeded and unseeded plots (Areas "B" and "C", above), but treatment applications and seeding were completed in September 1993 ("fall") instead of July ("spring"). The intent of these plots was to compare and quantify the effects of fall seeding and no seeding with spring applications, and to determine the relative effect of natural seed rain on establishing a protective native plant cover on disturbed sites. The data summarized in Figures 6 and 7 illustrate the relative effects of these treatments.

The data in Figure 6 generally illustrate the same basic principles observed in all other revegetation plots in the New World District. Applications of incorporated organic matter together with surface mulching with erosion blanket generally result in greater first growing season biomass than other treatment combinations. Main treatment effects illustrate the relative importance of mulch and organic matter, although the data show that mulching had a significantly greater effect on biomass than organic matter. The interactive effects suggest this same conclusion; use of organic matter and mulch together have about the same effect as mulching alone, with no apparent significant differences between the treatments. However, when mulch is not included, either with or without organic matter applications, biomass production appears to be significantly reduced from treatments where mulching was used.

Figure 7 illustrates the data collected from the McLaren fall unseeded plots. These data appear to be statistically very weak, hence making too many deductions is inadvisable. However, it is clear that total biomass production on these unseeded plots is considerably less than that found on the seeded plots, indicating that seed rain during the first growing season was not a significant contributor to the total biomass produced on seeded plots. Due to the large amount of statistical variability in the data, it is doubtful that reliable inferences can be made about the relative effects of the various treatments applied, and such interpretation will be delayed until future data sets are collected in future years.

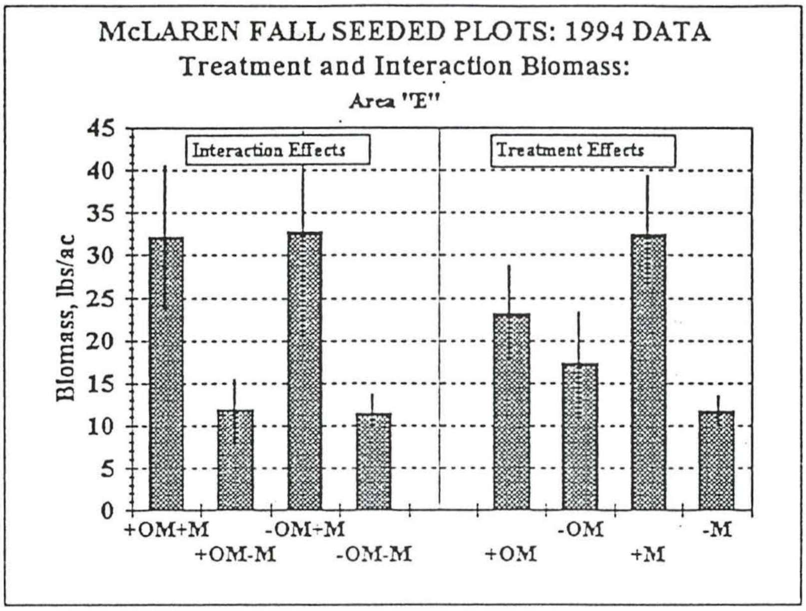


Figure 6: Biomass of the McLaren Mine fall seeded plots (Area "E") in 1994 showing main treatment effects (right) and interaction effects (left) of treatments. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

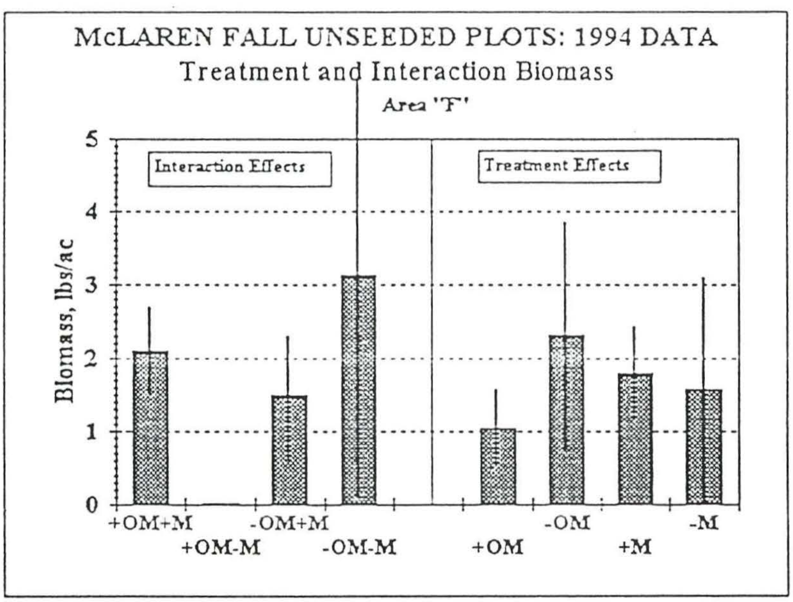


Figure 7: Biomass of the McLaren Mine fall unseeded plots (Area "F") in 1994 showing main treatment effects (right) and interaction effects (left) of treatments. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

Of considerable interest in these data sets, however, are the relative differences observed between spring-seeded and fall-seeded plots. It has been our firm contention that fall seeding should be practiced at these high elevations to mimic the natural distribution and casting of native seeds, which is then naturally followed by dormancy under the winter snow. However, the data observed so far in this study appears to cast doubt on that argument, and indeed suggest the argument may be totally false. A natural reaction by one interested in revegetating these sites would be that spring seeding appears to far out-perform fall seeding in terms of biomass productivity, and conclude therefore that fall seeding is truly a poor choice of methods. However, because there were so many data sets and overwhelming evidence supporting this suggestion in previous years, we feel it may be premature to form any opinions based solely on the 1993-94 data alone. We feel it is far too early to have any confidence in these data, and despite the apparent significance of the question, we defer drawing further conclusions about them until at least one more year of data have been collected.

Area "G": McLaren Mine single-species plots:

Sets of single-species plots were installed in September 1993 on both the McLaren Mine and the Glengarry Adit (Area "O", below) sites to determine the relative performance of each species used in the seed mixtures individually, under the maximum level of amendment intensity used. These plots are also intended to determine the performance of the "Peru Creek" population of *Deschampsia caespitosa*, originally collected in Colorado by R. W. Brown in 1978. This population is reported as having a very high level of adaptability to acidic substrate conditions, and the hypothesis that it will prove equally as well adapted as local populations is to be tested in these plots. Of the five original species seeded on the other plots in a mixture, their individual performance under interspecific competition conditions makes assessment of relative adaptability difficult to assess. Therefore, the single-species plots are viewed as potentially valuable sources of data concerning the relative adaptability of each individual species to specific amendments and site treatments.

The single-species plots were installed using all the most intensive treatments used on other plots in the 1993 study, including liming with hydrated lime, fertilizer (16-16-16 at 100 lbs N/ac, $P_2O_5$ at 200 lbs/ac, and $K_2O$ at 100 lbs/ac), organic matter incorporation, seeded, and then surface mulched with erosion netting. All the seed used was collected locally in 1992 and 1993 from surrounding meadows near the McLaren and Glengarry sites, and seed viability had been tested to verify optimum germination.

The data in Figure 8 show the mean biomass of each individual species following one year of growth and development. Generally, slender wheatgrass had the highest production, and Peru Creek tufted hairgrass had the lowest. Among the principle local varieties of each species, slender wheatgrass and alpine bluegrass were the most productive, followed by trisetum, tufted hairgrass, with alpine timothy the lowest. Every individual species has greatly different physiological requirements and tolerances, and because climatic conditions vary so widely from year to year, it is difficult, if not impossible, to draw firm conclusions about each species' performance based on just one year of data. The relative viability of the seed of each species varies from one year to the next, hence the performance in one year may vary greatly from what

it might be next year under otherwise similar conditions. Thus, additional years of assessment are required to be definitive about the results of this plot set.

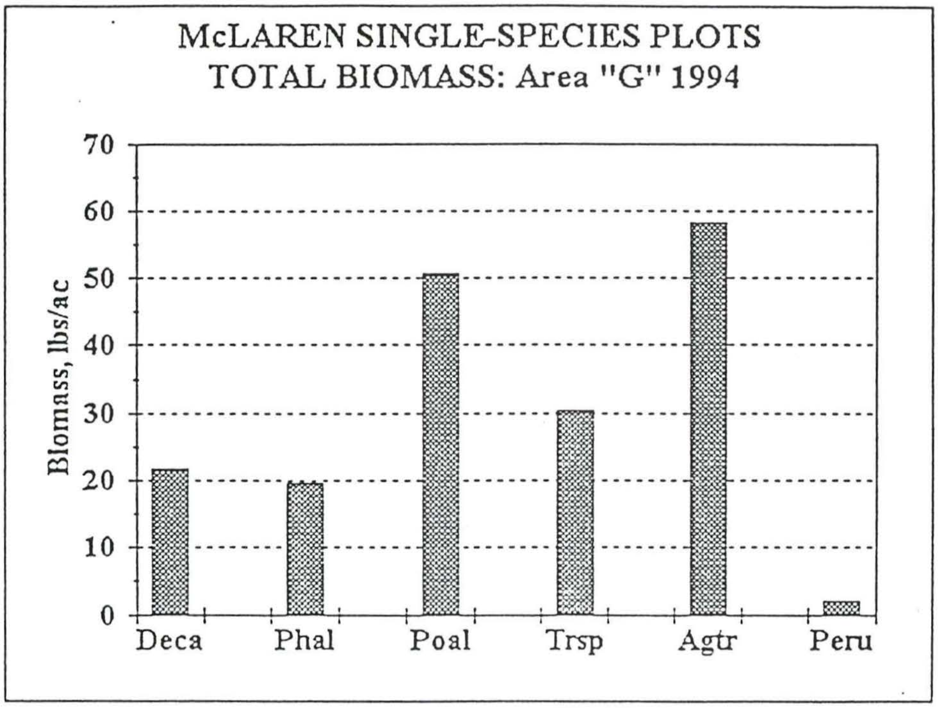


Figure 8: Biomass productivity data of the single-species plots on the McLaren Mine (Area "G") collected in 1994. Abbreviations include: Deca *Deschampsia caespitosa* (tufted hairgrass); Phal *Phleum alpinum* (alpine timothy); Poal *Poa alpina* (alpine bluegrass); Trsp *Trisetum spicatum* (trisetum); Agtr *Agropyron trachycaulum* (slender wheatgrass); Peru *Deschampsia caespitosa* Peru Creek population.

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Area "H": McLaren Mine transplant plots:

The transplant plots were installed in 1994, hence data will not be collected from these plots until 1995.

Area "I": McLaren Mine "phosphorus plots":

A set of "phosphorus" plots were installed on the McLaren Mine near the fall seeded and unseeded plots (immediately south of the Demonstration Area) in 1993 to determine the effects of phosphorus enhancement on plant growth, development, and soil formation. The role of phosphorus in acid spoils is generally well understood, but the effects of this nutrient on New World spoils has not been previously investigated. A set of 12 plots, each plot being 2m x 2m in

size, treated with either 50, 100, 200 or 400 lbs of $P_2O_5$ , replicated three times, was installed. The spoil had been limed, fertilized, treated with incorporated organic matter, seeded with the same seed mixture as all other plots, and mulched.

The data illustrated in Figure 9 shows the relative effect of P enhancement. The effect of increasing rates of P fertilization showed a nearly straight line increase in biomass productivity of the native plants used in the mixture on these plots. Obviously, P is relatively unavailable in acid mine spoils, and enhancement of available P dramatically increases biomass productivity.

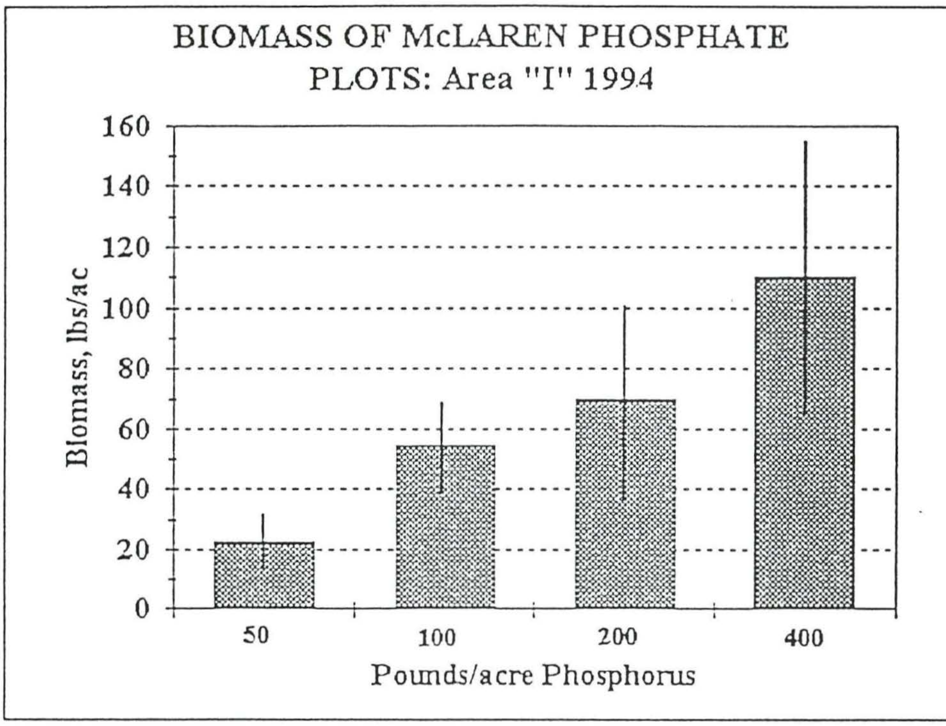


Figure 9: Biomass productivity of the McLaren Mine "phosphorus" plots (Area "I") in 1994. Rates of applied P are shown on the X-axis.

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<u>Area "J": McLaren Mine Organic Matter Plots</u>:

In September 1993 four small plots, each 2m x 2m (see plot maps in Appendix 1 and amendment rates in Appendix 2), were installed with the most intensive levels of treatments used in the other plots installed (lime, fertilizer, seeded, mulched), but were treated with varying levels of incorporated organic matter in the spoil material (peat moss). The levels of incorporated peat moss included: 0.25% (by weight of one acre-slice), 0.5%, 1.0%, and 2%.

Total plant biomass response data are illustrated in Figure 10 for the various organic matter incorporation rates used in these plots. Generally the data show inconclusive results because of a very high degree of variability among plots. We suspect that organic matter may

have a minimum threshold level in spoils material at which it becomes effective, and the 0.25% rate may have exceeded that minimum value. Therefore, it is possible that the variation observed among treatments is natural variability, although a stronger statistical sampling scheme may be required in 1995 to determine this with certainty.

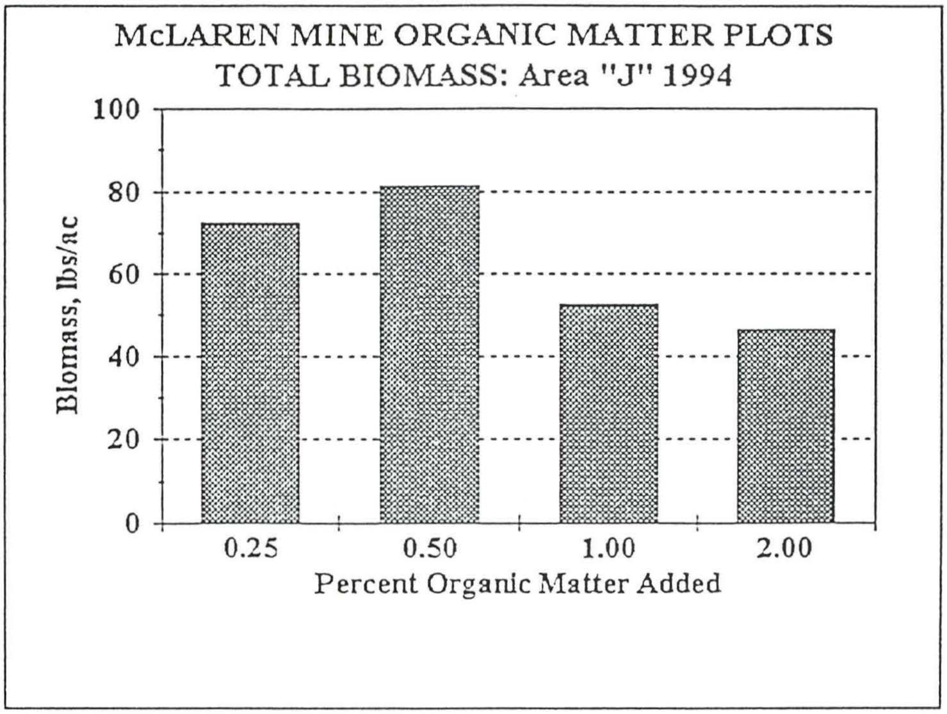


Figure 10: Total plant biomass productivity of the organic matter plots (Area "J") on the McLaren Mine in 1994. The sampling scheme used in 1994 did not yield a strong enough statistical sample size to account for variability.

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## FISHER MOUNTAIN ROADCUT SITE

### Area "K": Fisher Mountain Roadcut Plots:

The Fisher Mountain roadcut plots, established in September 1993, are located above the McLaren Mine along the road to Fisher Mountain, and occupy an old road cut that had been smoothed and contoured in 1992. The main treatments tested on this site included: (1) seeding vs no seeding, and (2) mulching vs no mulching, plus interaction effects.

The data illustrated in Figure 11 show that seeding resulted in the highest levels of total biomass and not seeding resulted in the lowest, regardless of mulching treatment. However, mulching and seeding, as expected, resulted in the highest biomass production. One of the key observations made from these data, however, is the quantitative effect that erosion blanket surface mulch provides for seed trapping of native seeds. The data clearly show a significant

increase in total plant biomass from trapped seed on mulched areas compared with unmulched areas.

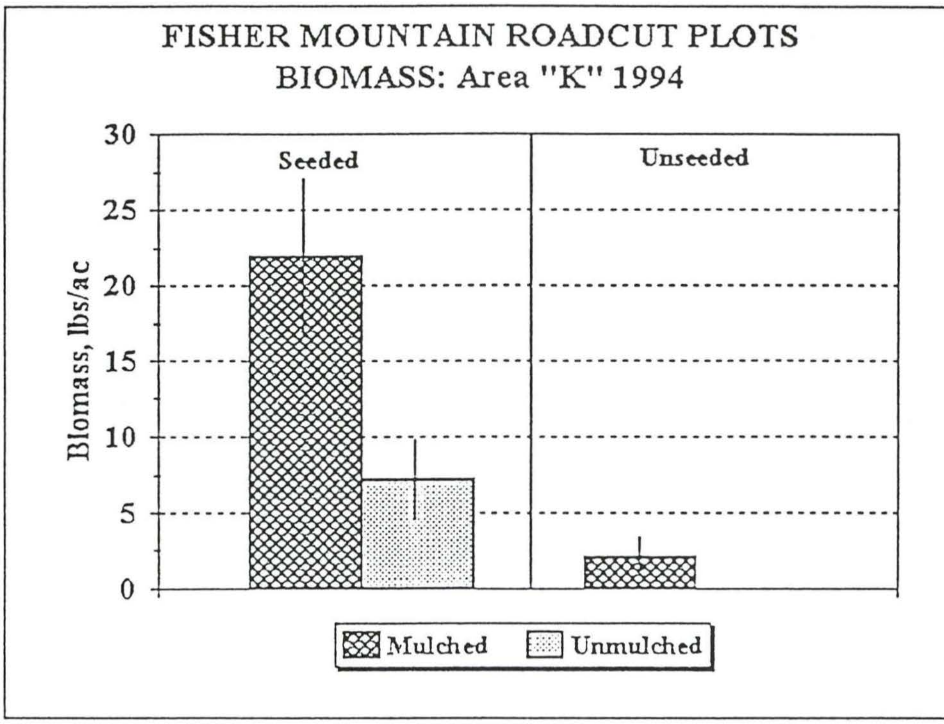


Figure 11: Total plant biomass on the Fisher Mountain Roadcut plots (Area "K") showing the relative effects of mulching vs no mulching, and seeding vs no seeding. Note the effect of mulch on seed trapping in the unseeded data.

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## GLENGARRY ADIT SITE

Area "L": Glengarry Adit spring seeded plots:

The spring seeded plots were installed on the Glengarry Adit site in July 1993, on the far southwest side of the contoured mine dump. The spoil material on this site, as throughout the entire dump, is extremely rocky and difficult to work during revegetation and plot installation. The entire area was limed with hydrated lime (see Appendices 1 and 2) at rates determined by local spoil pH and other conditions, the lower half of each plot set was treated with incorporated organic matter, and then was fertilized, seeded, and half the plots were covered with surface mulch (erosion blanket) in a random design. Spring unseeded plots were not installed on the Glengarry Adit site because the dump was smaller and much rockier than expected. The remaining area of the dump was devoted to the other experiments (Areas M, N, O, and P,

discussed below) because we felt those data would be more useful than that of another spring unseeded plot, which was already available on the McLaren Mine (see Area C above).

The data in Figure 12 illustrate the total biomass productivity response of plants on the Glengarry Adit site following spring seeding in 1993. The main treatment effects (right) show that organic matter and mulch both resulted in significant increases in total biomass, but unlike other plots, organic matter was more important than mulch on this site. It is probable that plant growth in the high rock content of this site was affected more by organic matter and its potential influence on nutrient and water retention than by mulch effects. The apparent importance of organic matter on this site is illustrated also by the interactive effects, whereby all organic matter incorporated treatments had much higher total biomass productivity, regardless of mulching treatment, than plots with no organic matter at all.

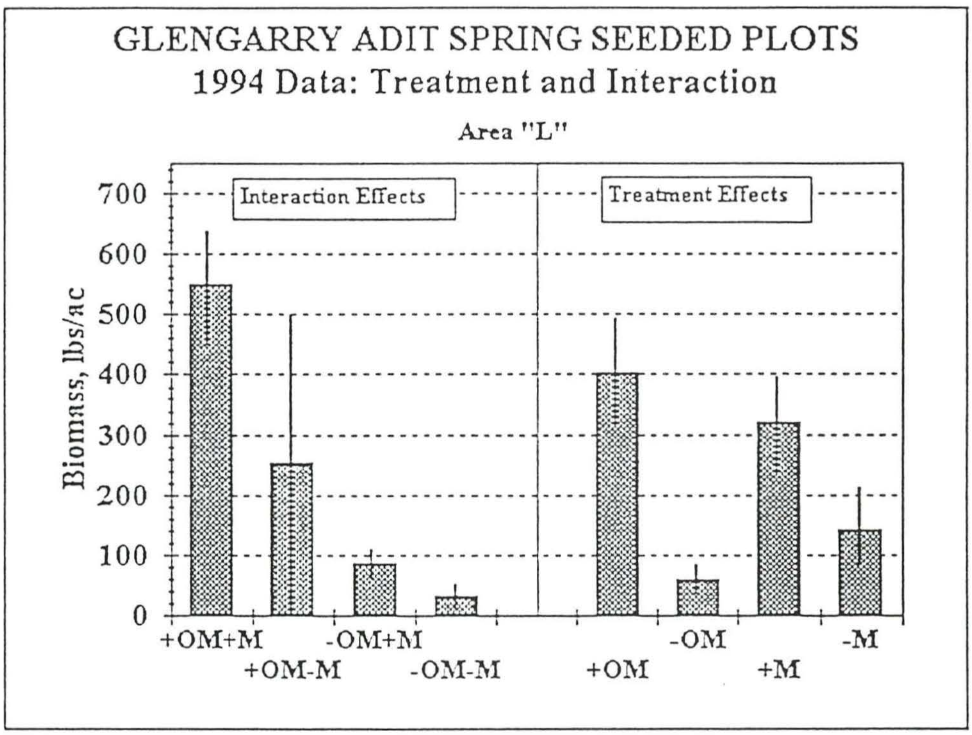


Figure 12. Total plant biomass productivity on the Glengarry Adit spring seeded plots (Area "L") in 1994. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

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Of significance is the relatively high level of biomass productivity observed on this site compared with other plots and locations. Like the McLaren Mine spring seeded plots, the spring seeded plots on the Glengarry Adit site had much high biomass productivity than fall seeded plots. This can partially be attributed in the first year to a much longer growing season period in 1993 for the spring seeded plots than for the fall seeded plots. In addition, the high degree of

variability in the data, reflected by large standard errors, suggests that more intensive data collection may be required before definitive conclusions can be reached. It is estimated that over 90% of the total production on this site was contributed by *Agropyron trachycaulum* alone, suggesting that this species is especially well suited during the first year to conditions on the Glengarry Adit mine spoil site. Judgement is being reserved about the relative effectiveness of spring vs fall seeding on these sites in the New World District because the data appear to conflict greatly with data collected in other years and in other studies. We are uncertain if climatic conditions may have contributed to the unexpected, yet overwhelming increases in biomass observed in the spring seeded plots compared with the fall seeded plots, if other yet unknown and undocumented conditions prevailed that may have been responsible, or if the responses observed are real.

Areas "M" and "N": Glengarry Adit fall seeded and fall unseeded plots:

The fall seeded and unseeded plots on the Glengarry Adit site were installed in September 1993 on the northeast side of the dump pile. Although the spoil material was equally as rocky and difficult to work as was the spring seeded plot site, we felt that a fall seeded and unseeded set of plots would yield useful data about various amendment alternatives and also permit an evaluation of the potential for using natural seed rain as a seed source in restoration. In addition, these alternatives could be compared with similar treatments on the west side of Fisher Mtn. located on the McLaren Mine, and thus provide even more useful data when compared over a larger area than just one site or mine dump.

The amendments and other treatments applied during installation of the fall seeded and unseeded plots were similar to those applied on the McLaren Mine (Areas "E" and "F", discussed above; see appendices 1 and 2).

Total plant biomass data collected from these two sets of plots are illustrated in Figures 13 and 14. As on the McLaren Mine, the biomass produced on the fall seeded plots in 1994 was only a few percent of that produced on the spring seeded plots (Area "L", above), suggesting that spring seeding may be more productive for early surface stabilization. Although this may certainly have been the case in 1993-94, we are reluctant to suggest this as a general rule. Conditions are highly variable from year to year in the New World District, and there is no certainty that spring seeding will consistently produce the kind of results observed here. Also, the total species diversity (number of different plant species on the site) on the spring seeded plots appeared to be much lower than that on the fall seeded plots. This indicates, with little quantitative data in support, that the spring seeded plot biomass is almost totally composed of one species (*Agropyron trachycaulum*), and that 1993-94 may have been particularly well suited for that species.

As expected, the relative effects of the different treatments and amendments on plant biomass were similar to those observed throughout the research. The highest total biomass production occurred on plots treated with organic matter and mulch, although on the fall seeded plots mulch had a much greater effect than did organic matter. Main treatment effects and

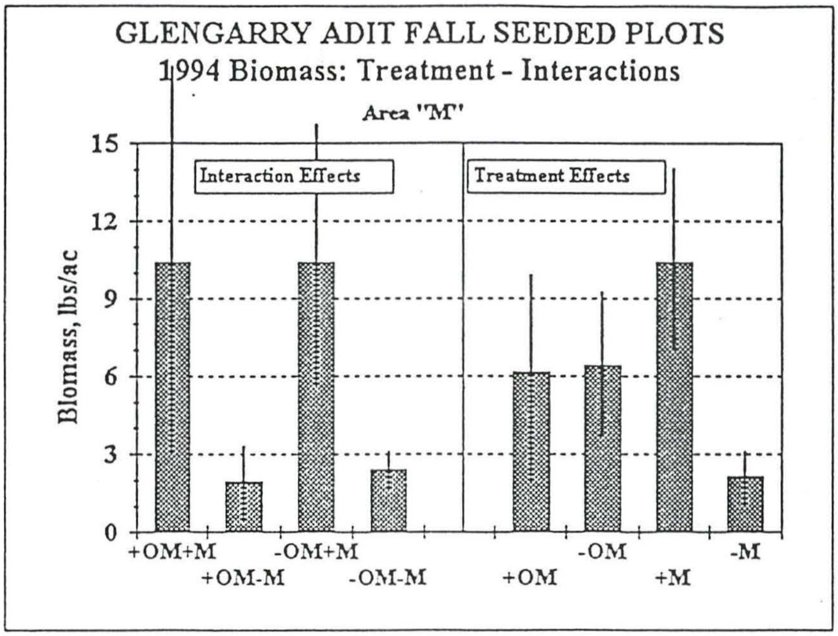


Figure 13. Total plant biomass on the Glengarry Adit fall seeded plots (Area "M") in 1994. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

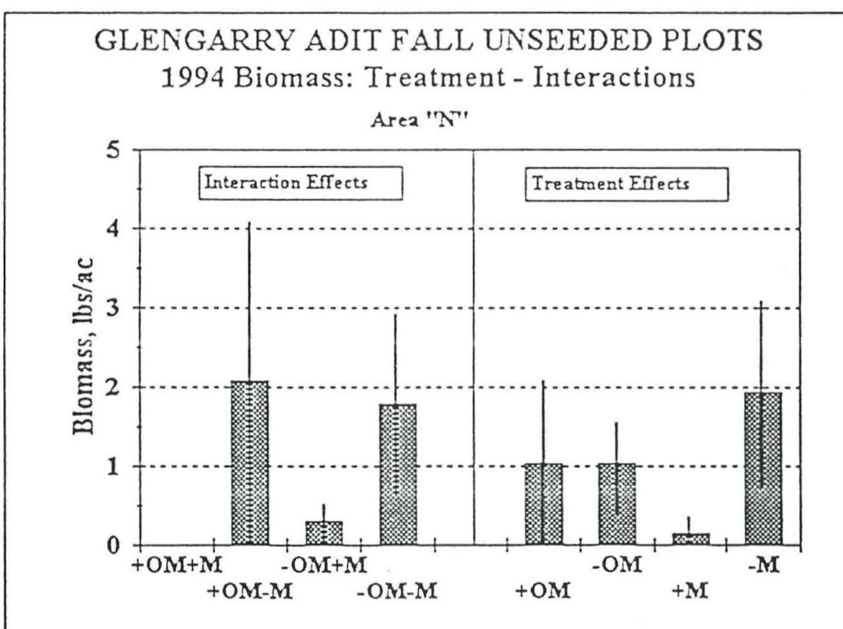


Figure 14. Total plant biomass on the Glengarry Adit fall unseeded plots (Area "N") in 1994. Abbreviations include: +OM incorporated organic matter; -OM no organic matter incorporated, +M mulched; -M not mulched.

interaction effects (Figure 13) on the fall seeded plots suggests that mulch is more important than organic matter during the first year. This apparent contradiction between these data and those observed for Area "L" (above, spring seeded plots) is troubling, and indicates that more observation is required before definitive conclusions can be reached. The high degree of statistical variability in the 1994 data also weakens any attempts to draw firm conclusions.

Figure 14 illustrates the total biomass data collected from the fall unseeded plots (Area "N") on the Glengarry Adit site. The high statistical variability in these data weakens any conclusions that may be made, and thus are probably best left out of the discussion until firmer and statistically stronger data-sets can be collected in future years. Virtually every major treatment effect in these data is directly opposite of that observed on other sites, and exactly opposite of expectations. With such large standard errors, we feel they are not reliable data at this point. However, the total biomass data, regardless of treatment, may be useful in suggesting the potential for natural seed rain on the site. Obviously, native seeds are moving onto this and other sites in the area, and these data do suggest some quantitative limits to that contribution, at least for the 1993-94 period.

Area "O": Glengarry Adit Single-Species plots:

The single-species plots on the Glengarry Adit site were installed, similar to those on the McLaren Mine (Area "G", above), in the fall of 1993, and were treated with various amendments representing an intensive level of application input (see Appendices 1 and 2). A total of 6 different plant species were seeded, individually (one species in each plot).

The data for total plant biomass are illustrated in Figure 15. As on Area "G" on the McLaren Mine, the individual species on the Glengarry Adit site responded quite differently to the treatments applied. *Agropyron trachycaulum* and *Poa alpina* had the highest total biomass by far over the other species. However, the performance over-all was quite disappointing, and somewhat surprising because the more aggressive species on many spoil piles, such *Deschampsia caespitosa*, *Phleum alpinum*, and *Trisetum spicatum*, had very low total biomass on this material. Despite the high level of treatment intensity applied to these spoils, it was apparently insufficient for the normally more aggressive species to produce higher biomass productivity, and yet *Agropyron trachycaulum* and *Poa alpina* responded better than expected. Therefore, it is probable that the data collected were insufficient to draw definitive conclusions after only the first year of growth.

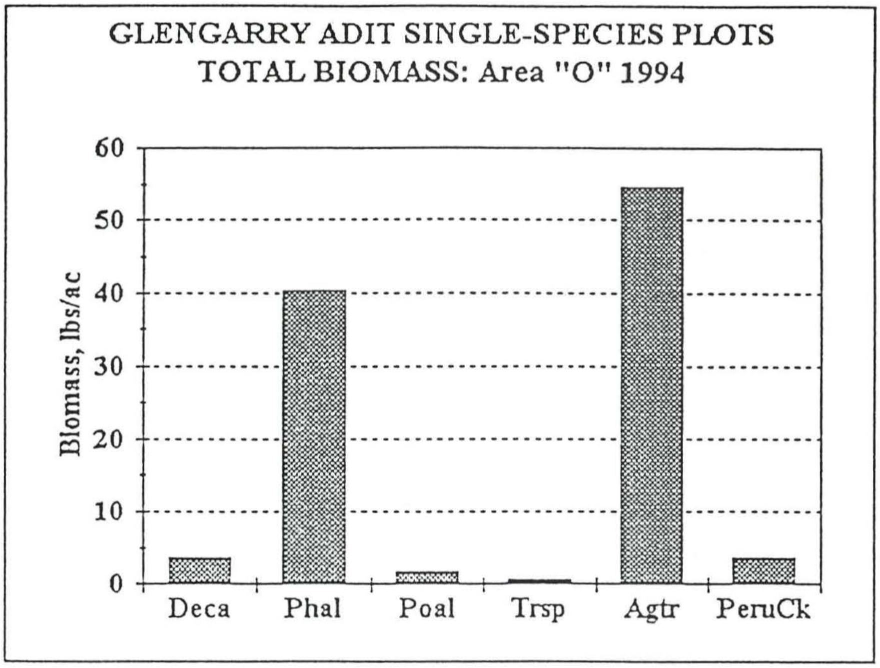


Figure 15. Total plant biomass on the Glengarry Adit Single-Species plots (Area "O") by species. Abbreviations include: Deca *Deschampsia caespitosa* (tufted hairgrass); Phal *Phleum alpinum* (alpine timothy); Poal *Poa alpina* (alpine bluegrass); Trsp *Trisetum spicatum* (trisetum); Agtr *Agropyron trachycaulum* (slender wheatgrass); Peru *Deschampsia caespitosa* Peru Creek population.

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Area "P": Glengarry Adit transplant plots:

The Glengarry Adit transplant plots were installed in September 1994, hence no data will be collected until the 1995 growing season.

## SOIL SAMPLE DATA

Soil samples were collected from each revegetation-restoration plot in 1994, including the McLaren Demonstration Area retreated plots. Soil analyses completed so far include just pH, which were collected to verify the effect of liming each plot. The original pH data collected before any lime or other treatments were applied to any of the plots ranged from 2.4 to 5.2 (see Appendix 3 for original data). The data shown in Table 2, below, summarizes the pH data one after application of lime and other treatments, and verifies that spoil pH was adjusted significantly on all but one or two plots where lime requirements exceeded our original estimates (e.g., see Table 2, Area C, plot 8).

Table 2. Summary of soil pH data collected from the 1993 revegetation-restoration plots in 1994, one year following treatment with lime and other amendments

## NEW WORLD RESTORATION RESEARCH

Summary of soil pH data collected from revegetation plots 1994

| SITE | LOCATION | PLOT | TREATMENT | pH |
|---|---|---|---|---|
| A | MCLAREN DEEP-LIME | 1 | DL-OM | 7.9 |
| | | 2 | SL-OM | 6.1 |
| | | 3 | -L-OM | 2.3 |
| | | 4 | DL+OM | 8.6 |
| | | 5 | SL+OM | 7.0 |
| | | 6 | -L+OM | 2.1 |
| B | MCLAREN MINE SPRING SEEDE | 1 | -OM-M | 6.6 |
| | | 2 | -OM+M | 6.7 |
| | | 3 | -OM-M | 6.8 |
| | | 4 | -OM+M | 4.2 |
| | | 5 | -OM+M | 5.4 |
| | | 6 | -OM-M | 5.7 |
| | | 7 | +OM-M | 6.7 |
| | | 8 | +OM+M | 6.6 |
| | | 9 | +OM-M | 6.2 |
| | | 10 | +OM+M | 5.4 |
| | | 11 | +OM+M | 6.2 |
| | | 12 | +OM-M | 5.0 |
| C | MCLAREN SPRING-UNSEEDED | 1 | -OM-M | 4.8 |
| | | 2 | -OM+M | 6.5 |
| | | 3 | -OM+M | 5.3 |
| | | 4 | -OM-M | 4.1 |
| | | 5 | -OM-M | 6.4 |
| | | 6 | -OM+M | 4.1 |
| | | 7 | +OM-M | 6.8 |
| | | 8 | +OM+M | 2.7 |
| | | 9 | +OM+M | 5.3 |
| | | 10 | +OM-M | 4.1 |
| | | 11 | +OM-M | 5.7 |
| | | 12 | +OM+M | 7.0 |
| D | MCLAREN DEMO. AREA | 1 | CONTROL | 5.7 |
| | | 2 | FERTILIZER | 6.0 |
| | | 3 | FERT.+LIME | 5.8 |
| | | 4 | LIME | 5.9 |
| | | 5 | CONTROL | 4.3 |
| | | 6 | LIME | 5.6 |
| | | 7 | FERTLIZER | 6.3 |
| | | 8 | FERT.+LIME | 6.3 |
| | | 9 | LIME | 5.8 |
| | | 10 | CONTROL | 6.4 |
| | | 11 | FERTILIZER | 5.7 |
| | | 12 | FERT.+LIME | 6.2 |
| E | MCLAREN FALL SEEDED | 1 | -OM-M | 4.3 |
| | | 2 | -OM+M | 6.4 |
| | | 3 | -OM+M | 6.6 |
| | | 4 | -OM-M | 6.3 |
| | | 5 | -OM+M | 5.1 |
| | | 6 | -OM-M | 4.4 |
| | | 7 | +OM-M | 6.2 |
| | | 8 | +OM+M | 6.5 |
| | | 9 | +OM+M | 5.0 |
| | | 10 | +OM-M | 6.4 |
| | | 11 | +OM+M | 4.7 |
| | | 12 | +OM-M | 4.1 |
| F | MCLAREN FALL UNSEEDED | 1 | -OM+M | 5.4 |
| | | 2 | -OM-M | 6.4 |
| | | 3 | -OM-M | 6.2 |
| | | 4 | -OM+M | 5.9 |
| | | 5 | -OM+M | 4.9 |
| | | 6 | -OM-M | 4.8 |
| | | 7 | +OM+M | 7.0 |
| | | 8 | +OM-M | 6.4 |
| | | 9 | +OM-M | 4.7 |
| | | 10 | +OM+M | 6.5 |
| | | 11 | +OM+M | 4.8 |
| | | 12 | +OM-M | 6.3 |
| G | MCLAREN SINGLE-SPECIES | NOT C | | |

| SITE | LOCATION | PLOT | TREATMENT | pH |
|---|---|---|---|---|
| H | MCLAREN TRANSPLANTS | 1 | +L-F | 6.8 |
| | | 2 | -L-F | 3.0 |
| | | 3 | +L+F | 6.7 |
| | | 4 | -L+F | 3.3 |
| I | MCLAREN PHOSPHORUS PLOTS | 1 | 200 LBS | 6.7 |
| | | 2 | 100 LBS | 6.6 |
| | | 3 | 50 LBS | 4.0 |
| | | 4 | 400 LBS | 6.0 |
| | | 5 | 50 LBS | 5.9 |
| | | 6 | 200 LBS | 5.0 |
| | | 7 | 400 LBS | 6.5 |
| | | 8 | 100 LBS | 4.5 |
| | | 9 | 400 LBS | 6.5 |
| | | 10 | 50 LBS | 6.2 |
| | | 11 | 100 LBS | 6.5 |
| | | 12 | 200 LBS | 6.7 |
| J | MCLAREN ORGANIC MATTER | 1 | 1.00% | 7.6 |
| | | 2 | 0.50% | 6.6 |
| | | 3 | 2.00% | 7.0 |
| | | 4 | 0.25% | 6.6 |
| K | FISHER MTN. ROADCUT | DATA N | | |
| L | GLENGARRY ADIT SPRING SEEDED PLOTS | 1 | -OM-M | 7.1 |
| | | 2 | -OM+M | 6.9 |
| | | 3 | -OM-M | 8.0 |
| | | 4 | -OM+M | 7.0 |
| | | 5 | -OM+M | 7.3 |
| | | 6 | -OM-M | 7.5 |
| | | 7 | +OM-M | 7.0 |
| | | 8 | +OM+M | 7.1 |
| | | 9 | +OM-M | 7.4 |
| | | 10 | +OM+M | 7.1 |
| | | 11 | +OM+M | 7.0 |
| | | 12 | +OM-M | 6.7 |
| M | GLENGARRY ADIT FALL SEEDED PLOTS | 1 | -OM-M | 6.8 |
| | | 2 | -OM+M | 7.7 |
| | | 3 | -OM-M | 7.0 |
| | | 4 | -OM+M | 10.5 |
| | | 5 | -OM+M | 8.0 |
| | | 6 | -OM-M | 8.0 |
| | | 7 | +OM-M | 7.4 |
| | | 8 | +OM+M | 9.7 |
| | | 9 | +OM-M | 9.4 |
| | | 10 | +OM+M | 7.0 |
| | | 11 | +OM+M | 11.1 |
| | | 12 | +OM-M | 7.5 |
| N | GLENGARRY ADIT FALL UNSEEDED PLOTS | 1 | -OM-M | 7.0 |
| | | 2 | -OM+M | 7.2 |
| | | 3 | -OM+M | 7.0 |
| | | 4 | -OM-M | 6.7 |
| | | 5 | -OM-M | 7.2 |
| | | 6 | -OM+M | 7.4 |
| | | 7 | +OM-M | 7.3 |
| | | 8 | +OM+M | 8.0 |
| | | 9 | +OM+M | 7.5 |
| | | 10 | +OM-M | 6.8 |
| | | 11 | +OM-M | 7.0 |
| | | 12 | +OM+M | 7.0 |
| O | GLENGARRY ADIT SINGLE-SPECIES PLOTS | NO DAT | | |
| P | GLENGARRY ADIT TRANSPLANT PLOTS | 1 | -L+F | 2.1 |
| | | 2 | L-F | 6.9 |
| | | 3 | -L-F | 2.2 |
| | | 4 | +L+F | 7.1 |

Area "Q": McLaren Mine Demonstration Area Reference:

The primary function of reference areas is to establish a baseline or "target" against which the developing plant communities on mine spoil sites can be measured in terms of rates of successional development and trajectories. The McLaren Mine Demonstration Area reference site has traditionally been located on the slope immediately north and above the Demonstration Area, and in 1994 this area was sampled for species biomass. The data collected on this site is illustrated in Figure 16, and generally shows the same kind of lifeform diversity as sampled in all previous years. The total biomass produced on this reference site has traditionally been near 400 lbs/ac, and 1994 was no exception. Additionally, the lifeform composition of the vegetation is generally made up of about 2/3 forbs and 1/3 grasses and grasslike (sedges and rushes) species on most reference sites near the McLaren Mine, and this site appears to follow that general rule in 1994. Perhaps surprising is the high degree of variability observed in native plant communities in the New World area from year-to-year. Although not depicted here, this variability can be substantial in some years, and appears to be closely related to the previous growing season's climatic and general environmental conditions.

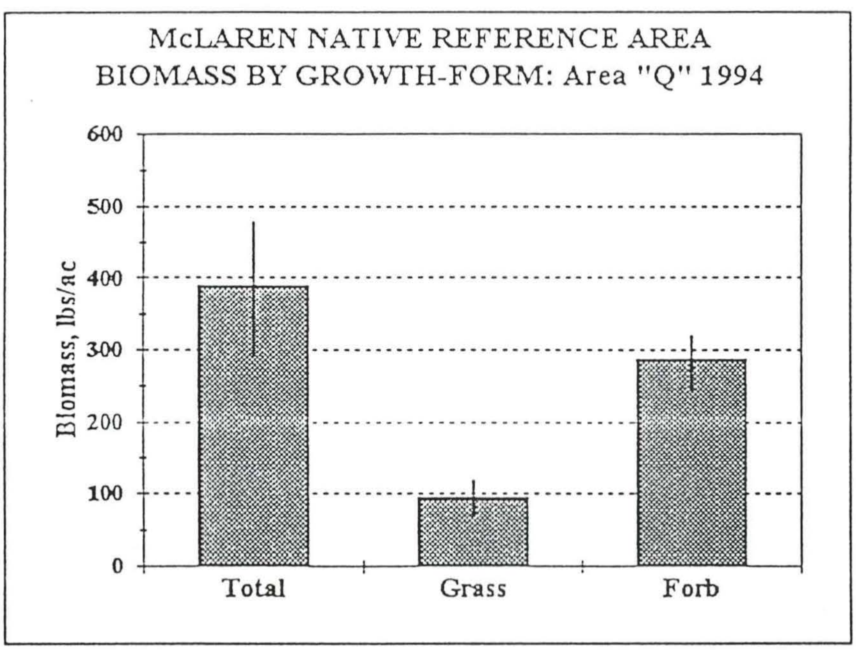


Figure 16. Total and lifeform biomass of the McLaren Demonstration Area Reference site (Area "Q") in 1994.

Data were not collected in 1994 from Areas R, X, Y, or Z.

2. **Installation of *Carex paysonis* transplant plots on the Glengarry Adit and the McLaren Mine sites.**

Transplant plots were not installed until near the end of the 1994 growing season, hence no data will be collected until the 1995 growing season.

3. **Re-fertilize the lower 2/3 of the plot area of the 1993 revegetation plots at the Glengarry Adit spring and fall seeded plots, the McLaren Mine spring and fall seeded plots, and the McLaren Mine deep-limed plots.**

The lower-2/3 of each individual revegetation plot installed in 1993 was re-fertilized with a pelletized 31-4--4 at the rate of 100 lbs N/ac, spread by broadcasting. No data will be collected until the 1995 growing season.

4. **Treat Fisher Creek tributaries (Sheep Mtn. tributary and others) with pelletized limestone to determine effect on metal loading.**

Not funded by Crown Butte Mines, but part of overall FS research effort. Data will not be collected until 1995. See M. C. Amacher.

5. **Pulse Fisher Creek with sodium hydroxide to determine effect on pH and metal loading.**

Not funded by Crown Butte Mines, but part of overall FS research effort. Data will not be collected until 1995. See M. C. Amacher.

6. **Sample water quality in Fisher and Daisy creeks.**

Not funded by Crown Butte Mines, but part of overall FS research effort. Data will not be collected until 1995. See M. C. Amacher.

7. **Sample soil surface erosion on all plots and adjacent reference areas with a rillmeter.**

Initial analyses of the 1993 data for surface roughness between sites and/or treatments shows that the Glengarry Adit site had a initial relative roughness of approximately 1-1/2 times that of the McLaren Mine sites. We believe this is due to the abundance of surface rocks at the Glengarry Adit site. When the 1994 data were compared against the 1993 baseline data, no differences were detected between treatments or mine sites except for relative surface roughness.

The Glengarry Adit site still continued to show a surface roughness of 1-1/3 times that of the McLaren Mine. While no differences were detectable, a trend of settling or compaction of the surface layer in all cases but two instances was observed. This is attributed to normal settling of the surface soil following seeding and other operations associated with the plot establishment.

**8. Re-assess the Miller Creek native plant seed garden, and re-treat with fertilizer.**

No quantitative data were collected from the native plant seed garden in 1994, although some significant decisions were made about its future utility (see discussion above under **Methods and Procedures**). The Miller Creek Garden was originally intended to serve as a seed-producing garden for native plant species used in revegetation of acid mine spoils. Although an excellent idea, the location of the garden proved to be unfortunate because the area is surrounded by highly aggressive plant species, both forbs and grasses, that are reinvading into the garden site and creating competition for the planted species. Attempts to remove the reinvading native species, although feasible, is extremely costly and perpetual. Because the desired species for which seed are needed can be more easily grown on acid mine spoil where competition would be greatly reduced, we recommend the following:

1. The Miller Creek garden site be terminated and allowed to return to a natural state. We feel that now disturbed, the Miller Creek garden site would be an excellent location to study the trajectory of meadow succession following severe disturbance.

2. Native seed garden sites be installed on the McLaren and Como Pit sites on acidic mine spoil material that have been moderately treated with appropriate amendments to support establishment and growth of native revegetation species. Competition from adjacent forbs and grasses would be minimized on acid spoils because most of the native plant species in the area are intolerant of those substrate conditions.

**9. Assess the retreated plots within the McLaren Mine Demonstration Area.**

See **Results** section, above, Area "D" for discussion of data.

**10. Collect and analyze soil samples within the McLaren Mine Demonstration Area, and compare with native reference soils.**

Soil samples were collected from the McLaren Mine Demonstration Area after it was noted that soil genesis appears to be occurring on the site. These samples were analyzed and the data compared with that of samples from adjacent native reference areas and with raw mine spoil data in an attempt to verify the degree to which soil development is occurring. The data

illustrated in Figures 17, 18, 19, and 20 summarize the relative comparisons of soil/spoil pH, %C, %N, and P for the three different soil types in the area.

Soil pH (Figure 17) of raw acid mine spoil from the McLaren Mine is typically about pH 3.0, and that of the native soil on undisturbed areas is generally close to pH 5. However, soil pH on the Demonstration Area, which was raw acid mine spoil in 1976 when the Demonstration Area was first installed with a pH near 3.0, has adjusted to pH levels more similar to that of natural soil at both sampled depths (about 0-6 cm and 6+ cm). The spoil material in 1976 was limed with hydrated lime and treated with incorporated organic matter (sterilized steer manure), so an argument can be made that current pH levels largely reflect the original treatments applied.

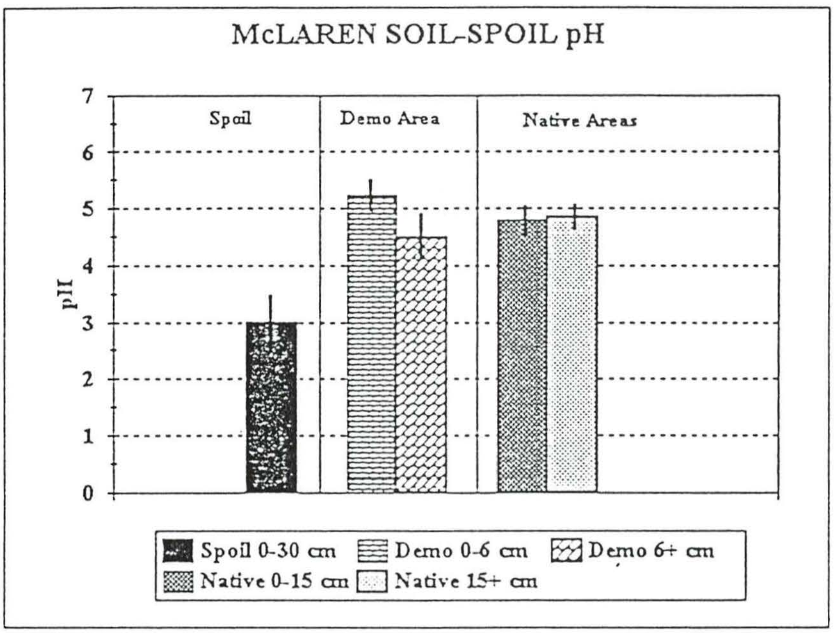


Figure 17. Soil pH analyses for soil samples collected from the McLaren Mine acid spoils, Demonstration Area, and the native reference area.

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Percent carbon (Figure 18) reflects the amount of organic matter in the soil, and the data show that the spoils in the Demonstration Area are beginning to approach levels more similar to those observed in natural soils than those of raw spoil material. Questions arise about the source of carbon observed in the mine spoil because experience would suggest that carbon levels should be very low in raw spoil material. However, we believe there may be confounding problems in the analysis of C, and the higher levels than expected in the spoil may reflect an interaction with Fe reduction. If this is true, the values may be biased, and hence may be unreliable. The trends illustrated are interesting, however.

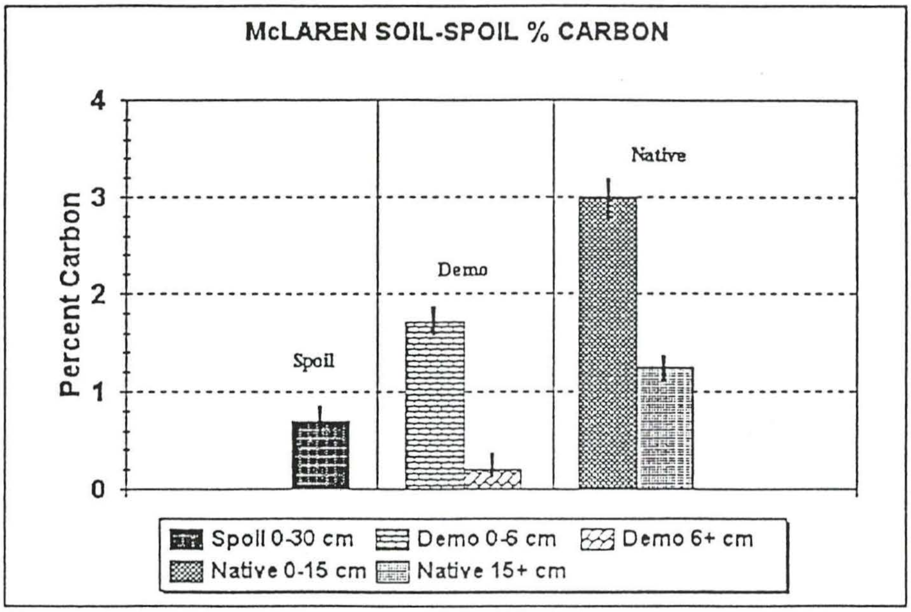


Figure 18. Soil carbon (C, %) analyses for soil samples collected from the McLaren Mine acid spoils, Demonstration Area, and the native reference area.

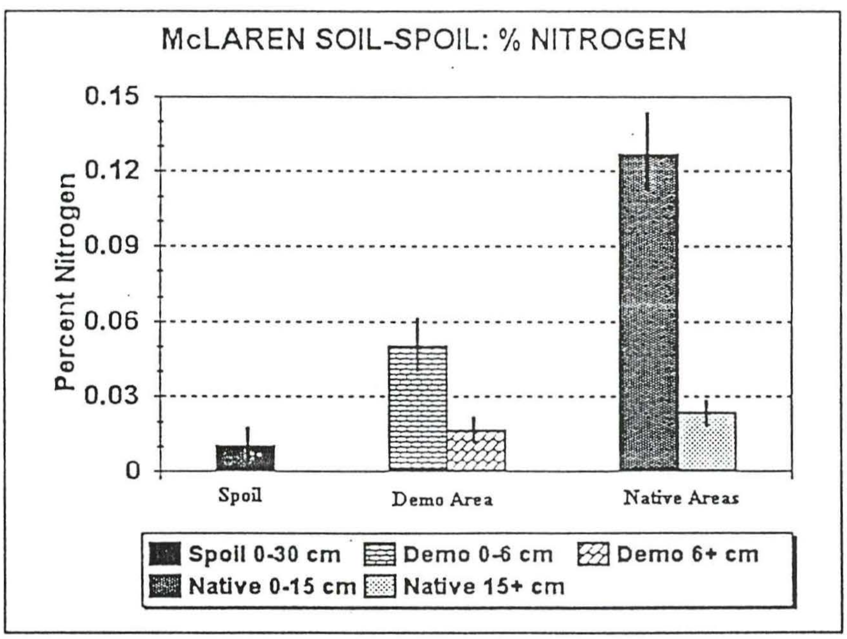


Figure 19. Soil nitrogen (N, %) analyses for soil samples collected from the McLaren Mine acid spoils, Demonstration Area, and the native reference area.

Percent nitrogen (Figure 19) is a measure of the total N in the soils, and reflects residual nutrient levels from nutrient cycling, fertilization, and other sources. Obviously some N is present in raw spoil material, probably originating from atmospheric sources, but that in the Demonstration Area suggests a trend toward natural levels observed in adjacent native soils. No doubt a portion of the N observed in the Demonstration Area resulted from artificial fertilization over the years at various times, whereas that in native soil is a product of nutrient cycling and natural nutrient inputs from outside sources.

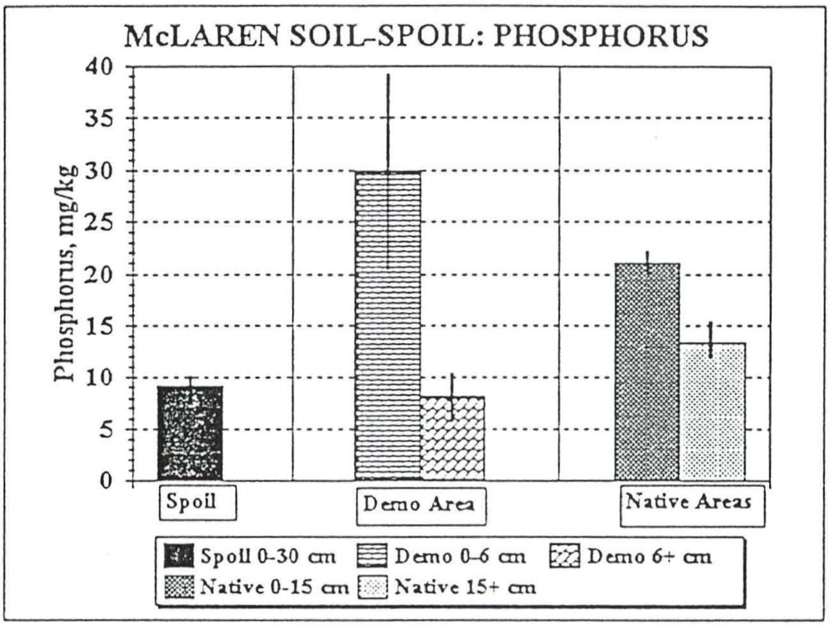


Figure 20. Soil phosphorus (P mg/kg) analyses for soil samples collected from the McLaren Mine acid spoils, Demonstration Area, and the native reference area.

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Phosphorus (Figure 20) is expressed in mg/kg of soil, and similar to trends observed with other nutrients and chemicals, reflects the general trend toward the maturation and development of natural soil in the Demonstration Area. The Demonstration Area was re-fertilized numerous times since 1976, and undoubtedly reflects residual P levels from these application cycles. However, P levels in the developing soil of the Demonstration Area clearly resemble that of native soil more closely than they do levels in raw spoil, from which they are derived.

These data strongly support the hypothesis that soil development is occurring on the Demonstration Area. These data suggest that soil genesis can probably be initiated on similar sites that are also intensively treated in a comparable manner in similar time scales as the McLaren Mine Demonstration Area.

## DISCUSSION

Among the more significant results learned from the 1994 data are the relative roles and levels of importance of the various amendments and treatments used in reclamation and restoration for the establishment of native plant communities on severely disturbed acid mine spoils. The relative effects of liming, both deep-liming and shallow-liming, use of organic matter incorporation, and surface mulching with erosion blanket are in the process of being established on the acidic mine spoils of the New World District.

**Liming:**

Liming appears to be absolutely essential on mine spoils with a pH below about 4.5 (Figure 2, Area "A"). No other treatment, including organic matter, mulch, fertilizer, seeding method, or other amendments appear to substitute for the effects of liming and pH adjustment. Therefore, we strongly recommend that reclamation and site restoration sites on acid mine spoils within the New World Mining District be limed with hydrated lime at rates appropriate for local specific pH levels and other soil characteristics (e.g., see Thomas and Hargrove 1984; Barber 1984; Sorensen et al. 1980). Appendix 3 contains some tables and guides for liming rates for various materials on the McLaren and Glengarry sites that we have used successfully. In addition, mine spoil properties for the various sites are summarized.

The greater biomass production observed on "deep-limed" plots (24 in.) vs "shallow-limed" (6 in.) plots vs "no limed" plots are consistent with expectations. The most significant result observed from these data so far show that, in addition to greater biomass and cover, rooting depth of first-year seedlings is significantly greater under deep liming than under shallow liming, and that liming at any depth results in significantly greater rooting depth than under no liming at all (no plants survived without lime). In addition, peripheral data on plant leaf water relations showed that plants experience less water deficits during midday water potential depression under deep liming than under shallow liming. These latter observations may not appear to be very significant at high elevations were water deficits are rarely important, but in such areas water deficits can devastate young emerging seedlings when they do occur. Plants in alpine ecosystems are normally not known for their water deficit tolerances (as are most desert plants), hence when periodic mid- growing season water deficits do occur at high elevations, they can have a major impact on plant survival. Deep liming appears to improve survival chances under these conditions by encouraging (or allowing) deeper root penetration and greater root architectural development and diversity with depth. Additionally, we anticipate that in future growing seasons deeper root development will also improve slope stability, enhance organic matter incorporation at deeper depths in the soil, and in general permit for greater diversity in plant community development.

Re-applications of lime in the form of crushed limestone on the McLaren Demonstration Area had inconsistent results so far. We are hoping to determine whether re-liming will raise spoil pH in areas where the effectiveness of the original lime application has diminished. In addition, perhaps re-applications of lime will enhance nutrient availability. However, crushed limestone reacts at extremely slow rates at high elevations and in cool environments. Hence more time is required to determine the actual results of this treatment. The data in Table 2 is

supportive of the hypothesis that liming can substantially alter pH levels, even of the worst spoil materials, and adjust spoil acidity to well within the tolerance limits of the native plant species adapted for revegetation. The "control" plot data for soil pH in Area "D" (Demonstration Area) in Table 2 show residual pH values from lime applications made in 1976, and these data illustrate that pH has not apparently fallen back to original levels, despite many years (18 years!) since first being limed.

**Surface mulching and organic matter incorporation:**

Surface mulching and organic matter incorporation in mine spoil materials do not appear to be absolutely essential for successful establishment of a protective plant cover in the New World District. However, the beneficial effects of these amendments are so overwhelming as to be considered extremely important for enhancing the rate of plant establishment on raw spoil material. The data clearly illustrate that these two amendments significantly enhance seedling establishment, native seed trapping, and the development of plant cover. Although the data are from first-year results only, previous experience in the area strongly suggests that these two amendments are highly important during the first one or two years of plant establishment. The primary advantages of surface mulching include:

1. enhances surface stability and reduces surface erosion due to wind and water.
2. reduces the redistribution of seed and soil fines by wind and water.
3. serves as a heat-trap that reduces the incidence of frost action.
4. reduces evaporation of water from the surface during seedling emergence and early establishment.
5. moderates surface temperatures during periods of extreme solar radiation.

The primary advantages of organic matter incorporation include:

1. complexes metals in spoil materials and reduces the concentration available to plants.
2. improves soil aeration and reduces compaction.
3. improves the water and nutrient holding capacities of mine spoils by providing greater chemically active binding sites.

**Fertilizing:**

Fertilizer was not a treatment variable in the 1993 plots, but based on experience is considered essential or extremely important to successful plant establishment on these sites, and in combination with the other amendments discussed above, is important during succession initiation. Acid mine spoils are typically nutrient-poor, especially the three primary macronutrients of N, P, and K. Acidic conditions reduce or interfere with nutrient availability to plants, and even if nutrients are present in high concentrations in acidic soils, pH levels below about 4.5 can result in significant reductions of nutrient availability. Artificial fertilization of acid mine spoils, combined with liming and other amendments, greatly increases the nutrient availability for plant establishment and growth. The exact chemical ratios of N-P-K used is probably not as critical as the actual application of fertilizer, but N and P appear to be the nutrients in greatest need on these substrate materials. We have successfully used various N-P-K

ratios, including 16-40-5, 16-16-16, and 31-4-4 depending on local spoil/soil properties and characteristics. In all cases we recommend fertilizer applications at the rate of 100 lbs N/ac (that is 100 pounds of Nitrogen per acre equivalent, NOT 100 lbs/ac bulk fertilizer!). The total amount of fertilizer applied may be as much as 625 lbs/ac (e.g., for a 16-16-16 fertilizer, 100 lbs N/ac = (100/0.16) = 625 bulk lbs/ac).

The more difficult question with fertilizer is the requirement for re-fertilization in subsequent years following revegetation. This issue is being addressed in the 1993 plots, and with only one year of data so far, definitive conclusions are not yet available. However, previous experience on the McLaren Demonstration Area suggests that refertilization for several years may be required on some sites in order to initiate and accelerate succession and soil genesis. The primary danger in refertilization is related to the principle plant species used in revegetation; grasses are notorious luxury-consumers of N and other nutrients. Refertilization may favor grasses significantly, and may thus retard succession and invasion by forbs and other lifeforms of native plants. This concern may be real, but quantitative limits for most grasses and forbs have not been established yet, and therefore we cannot be definitive about regulating and balancing refertilization schedules and nutrient ratios.

Phosphorus nutrient enhancement appears to have some striking impacts on plant growth on these spoil materials. P is commonly required for root, flower development, and seed production in higher vascular plants. At high elevations in cool environments, rooting can be an extremely slow process, and seed production is absolutely essential for plant spread and reproduction into distant areas. Many alpine plant species, especially later seral species, frequently rely on vegetative reproduction. But lower seral species, such as many of the grasses and grasslike plants (sedges and rushes), are luxury consumers of N and P and other normally limited macro- and micro-nutrients. Although these are only first year data so far, the trends appear to be obvious; the more P supplement added, the greater the site biomass.

Seed trapping:

Native seed trapping on disturbed sites provides a potential means of accomplishing revegetation using natural succession and colonization by invading plant species, and it holds some highly compelling and tempting possibilities in wildland restoration. The unseeded plots established in 1993 were installed to test the hypothesis that native seed trapping could be enhanced by utilizing various amendments. Although only one field season has elapsed since installation, it is clear that surface mulching significantly improves seed trapping on disturbed sites. The data at this early date might suggest that native seed trapping is not rapid enough, and hence not a reliable enough method, and that native seed trapping should perhaps be relied on more as a supplement to artificial seeding with native species. Although 1994 may not be a typical year, or perhaps more than one year of seed trapping may be required to achieve adequate ground cover and surface protection, more plot assessment will be required in future years to adequately address the issue. We know with certainty that native seeds are bombarding disturbances constantly, but that most of those seeds are unable to lodge in "safe-sites" and become established because of limiting physiological conditions at the surface of those disturbances. The hypothesis that surface conditions can be ameliorated, that treatments can be applied to enhance the entrapment of those seeds, and that artificially through reclamation and

restoration treatments a site can be made more habitable for seedling establishment and development, is a worthy goal requiring more study and research. It would seem totally irresponsible to ignore and not take advantage of the natural sources of native seeds that are constantly, year after year, being made available for natural revegetation of disturbed lands.

The "triangle" area on the east end of the McLaren Demonstration Area is an example of natural seeding and seed trapping on a site that may have considerable significance for revegetation of severe acid mine disturbances. On this small site, the spoil material was treated with lime, fertilizer, organic matter, and surface mulch in 1976, but was not seeded or planted. In 1994, some 18 years later, the area is continuing to receive considerable seed rain from adjacent plant communities, and the small plant community developing on the site currently has a very high species and lifeform diversity. However, the establishment of a protective cover of vegetation occurred slowly over a period of about 10 years on the "triangle" area (although after 18 years, no cover was established on untreated and unameliorated areas). It is possible that periodic refertilization of the "triangle" area during the first three to five years may have accelerated vegetation development, but we have no data to substantiate just how effective retreatments can "push" succession on severe disturbances.

The issue requires additional research because we have a poor understanding oh how the effectiveness of seed rain and seed trapping could be enhanced and utilized in conjunction with artificial seeding, or alone. There appears to be no question that amelioration of limiting spoil properties with various amendments enhances seed "safe-sites", seed germination, seedling establishment, and plant growth on disturbances. Also, there is little debate that surface conditions can be manipulated (either by earth moving equipment and or use of erosion blanket materials) to enhance the trapping efficiency of the site for native seeds. However, the percentage gain in plant cover and species diversity may be questionable, but at present we cannot definitively and quantitatively address the issue until more extensive data are collected. During the first growing season, natural seed rain and seed trapping appear to have contributed about 3-10 percent gain over untreated areas, while only producing about 1 to 5% of the biomass productivity of seeded areas.

**Seed application schedule:**

The spring vs fall seeding experiments on the McLaren and Glengarry sites were surprising because the results were opposite from those expected. Experience and basic theory suggest that fall season seeding is most favorable, especially in harsh high elevation climatic zones in the Northern Hemisphere, due to climatic and plant phenology patterns. Many of the native species at high elevations have definite requirements for physiological dormancy before seed germination can occur, and even in cases where dormancy is not required, physiological mechanisms are closely modulated by previous environmental history. Thus, if various enzyme and other biochemical ratios are not in balance, which normally are achieved during dormancy, seed germination is either prevented, altered, delayed, or early seedling formation is aborted. Thus, the normal phenology of many harsh climate native plant species ensures maturity of propagules for dispersal late in the growing season or early in the fall just before snow accumulation signals the onset of physiological dormancy. The eons of evolutionary time have solidified this process over numerous generations in each plant species, suggestive that

mimicking the process of seed dispersal is best achieved by seeding in the fall of the year.

The fact that during the first growing season following seeding the spring-seeded plots had much higher biomass productivities and cover than fall-seeded plots is unexpected, confusing, and baffling. Until additional data are collected we will not be able to sort out the reasons why this response was observed. We currently believe (but cannot quantitatively defend) that local climatic conditions were conducive to spring seeding, and the rather mild temperatures in 1993 and 1994 may have contributed to this phenomenon. Although definitive explanation is not available, we caution against reading too much significance into the data collected so far (for 1994).

**Individual Species Performances:**

The relative viability and vigor of each species is highly variable from year to year, and despite claims by commercial seed growers and dealers to the contrary, seed quality is rarely a guarantee of species performance. The native plant species used in the research on the plots in the New World District were collected by hand from plants in local habitats of the ecosystem surrounding the area. Although many of these species are highly aggressive on disturbed sites, and are normally observed as early seral colonists on acid spoils, some seed collections have lower viability and germinability than others. Such appears to have been the case with the seed used in 1993. We anticipated greater viability and establishment of some species than we observed, while in others we expected lower establishment than observed. Even after 22 years of working with these species, surprises are still common. For example, the *Agropyron trachycaulum* seed collected in 1992, and used on the plots in 1993, was apparently much more viable than previous seed lots would have suggested. On the other hand, seed of *Deschampsia casepitosa*, normally very aggressive and viable, was apparently of much poorer quality that year than in previous years. Additional data in future growing seasons will be required to sort out the long-term effects of this phenomenon. However, of some consolation is the reality that rarely are the seeds of all species of poor quality in any one given year.

**General recommendations:**

First-year reclamation data are rarely applicable or very useful for designing long-term solutions to the problems of reclamation and restoration of severe disturbances. Therefore, although interesting and suggestive of some long-term trends, the 1994 data alone probably cannot be relied upon to indicate long-term solutions. However, when tempered with data collected over the last 22 years, the 1994 data take on much stronger significance. Without defining quantitative limits, these data verify previous observations regarding the significance of the various amendments recommended for use in reclamation of disturbed mine lands in the new World District.

The generalizations made above about liming, fertilizing, organic matter incorporation, surface mulching, and species performances appear to be largely consistent with expectations derived over the last 22 years. Although we are uncertain about the data collected from spring vs fall seeded plots, and in some cases for the "single-species" plots, on the McLaren and Glengary sites, the overall responses of the various amendments and combinations of treatments follow expectations. The data collected so far suggest that the following general procedures for

reclaiming surface exposed acid mine spoils in the New World District have a very high probability of leading to natural community-system restoration:

1. Where possible, the natural soil should be saved and re-spread over the disturbance prior to revegetation and restoration. Unfortunately, very few of the older disturbances, except perhaps for some road cuts, have available native soil. The road re-contouring and shaping work completed by Crown Butte Mines on Henderson and Fisher mountains appears to be utilizing what natural soil is available, and the favorable results of revegetation efforts reflect the value of this approach.

2. Shape and contour disturbed areas to the approximate original natural slope and topographic conditions. Concerns about drainage and ponding of accumulated water can be managed during this step. The road re-contouring work and the drainage diversion channels constructed on the McLaren and Como sites are excellent examples of how this step should be implemented. The surface shaping of the spoils at both locations in 1993-94 was particularly impressive because operators were sensitive to localized colonies of *Carex paysonis* and other species that were preserved and incorporated into the completed site. In addition, the surface work appeared to mimic natural conditions by providing a diverse topography of exposures, slopes, and shapes that should optimize seeding, seed trapping, and plant development, while minimize severe wind scour and other extreme conditions.

3. Analyze the soil/spoil properties of substrate materials near the surface. In the New World District, the general properties of greatest interest and concern include soil pH, availability of macronutrients such as N-P-K, and concentrations of toxic chemicals such as metals.

4. Apply soil amendments specifically designed to ameliorate the limiting factors identified by the soil analyses above. These include:

    a. Liming spoils with pH values lower than about 4.5-5.0, and incorporating the lime into at least the upper 6-12" (but 24" is better) of spoil material. Rates of lime application will vary with local site conditions, but generally our experiences suggest rates from 2-4 tons/ac on the least toxic materials, ranging up to 10-20 or more tons/ac on the poorest areas (see Appendices 2 and 3).

    b. Organic matter incorporation to same depth as lime using sterilized manure, straw, peat, or other organic products to enhance nutrient retention and water holding capabilities, to minimize compaction and improve aeration. In addition, organic matter complexes (ties-up) toxic metals that may otherwise be available to plants. See Appendices 2 and 3 for approximate rates of application used.

c. Fertilizer applications to enhance the availability of primary limiting nutrients required for plant growth. Commercial sources of fertilizer with N-P-K ratios like 16-16-16, 21-8-8; 16-41-5, 31-4-4, and possibly others appear to be useful and beneficial for establishment of plants on these materials. N appears to be the most limiting macronutrient, followed by P. Therefore, we recommend application rates that provide 100 lbs N/ac and 200 lbs P/ac during the initial fertilization. Subsequent refertilizations in future years can probably be accomplished with heavy applications of N, but P and K may be less limiting. We suggest that re-fertilization treatments in years following initial installation of revegetation areas be accomplished with high N (100 lbs N/ac) and lower amounts of P and K. We do not have quantitative data for the New World area to substantiate that lower rates of re-fertilization with N will be satisfactory.

5. Observe natural succession on old disturbances in the New World District (such as road cuts and fills, old mine piles, etc.), and study the variability in volunteer plant species on different kinds of disturbances as a guide to species selection. The New World area is unusually rich in disturbances of various types and ages, hence has a wide variety of successional communities that should be used to identify native species adapted for use in reclamation of acid spoils.

6. Select native plant species based on observations made in 5., above (old succession areas). The total natural vascular flora in the Fisher Mtn. area, including Daisy, Fisher, and Miller creeks, probably numbers about 90-100 plant species, including grasses, forbs, shrubs, and trees. Based on our experience, about 8-10 of these (or about 10%) are adapted to conditions on acid mine spoil materials, being suitable for use in revegetation. These include the following:

| Species | Common Name | Lifeform |
|---|---|---|
| *Carex paysonis* | Payson sedge | sedge |
| *Deschampsia caespitosa* | Tufted hairgrass | grass |
| *Trisetum spicatum* | Spike trisetum | grass |
| *Poa alpina* | Alpine bluegrass | grass |
| *Phleum aplinum* | Alpine timothy | grass |
| *Agropyron trachycaulum* | Slender wheatgrass | grass |
| | | |
| *Sibbaldia procumbens* | Sibbaldia | forb |
| *Potentilla diversifolia* | Varileaf potentilla | forb |
| *Agoseris glauca* | Mountain agoseris | forb |

*Carex paysonis* is best used as a transplant species because seed germination is extremely unreliable and difficult (Haggas et al. 1987). We have seeded this species in various areas, and although immediate results are often disappointing, long-term results indicate

that seeds can germinate years after application. There are several species of *Carex* in the area, including *C. nigricans, C. phaeocephala*, and others, and all are particularly hardy plants, but only *C paysonis* appears to be especially well adapted to extreme acid conditions.

If seeds are available (either commercially, or can be collected by hand), we also recommend using the forbs listed above wherever possible. These species display considerable tolerance to acid mine spoils in some areas, although they usually grow best in the least toxic mine dumps. Following treatments with amendments mentioned above, experience suggests that seed trapping and natural succession should occur rapidly in subsequent years. The forbs appear to be aggressive during succession in subsequent years after revegetation if refertilization does not over-favor the grasses. On the McLaren Demonstration Area, invading forb species outnumber the grasses 3/1.

Seeding rates should be based on numbers of seeds desired per unit area (e.g., number of seeds per sq. ft.) rather than on pounds per acre. Every species has unique seed characteristics of mass and shape, hence total weights vary greatly from species to species. For instance, *Deschampsia caespitosa* commonly has about 1,750,000 seeds per pound, whereas *Agropyron trachycaulum* may have about 175,000 seeds per pound, a factor of 10 times difference. Therefore, if both species were seeded at the same weight per unit area, *Deschampsia caespitosa* would have a decided competitive advantage over *Agropyron trachycaulum* because of the difference in number of potential plants produced per unit area, assuming equal viability. One pound of seed per acre, assuming 100% viability, would provide 1,750,000/43560 = 40.2 seeds per sq. ft. of *Deschampsia caespitosa*, but only 4 seeds per sq. ft of *Agropyron trachycaulum*.

Therefore, seeding rates should be adjusted according to the individual seed characteristics of each species so that equal numbers of seed of each species are applied per unit area. This will minimize any competitive advantage of one species over another, although obviously some species are inherently more competitive than others (but because there are no quantitative indices of competition, this fact is conveniently ignored). Generally we attempt to provide about 75 to 150 seeds per sq. ft. per species (using 5 species, 75 x 5 = 375 total seeds/sq. ft.; see Appendix 2), depending on the severity of local site conditions (more severe sites require higher seeding rates). This may translate into total rates of about 25 to 50 lbs of total seed per acre, depending on the species used and site conditions.

Under natural conditions seed mortality is very high; we often experience 90% mortality during the first winter and growing season. Of those seeds that survive and germinate to become seedlings, mortality during the first growing season is also high; sometimes exceeding 75%. Mortality rates decline as plants mature into adult growth forms, hence as maturity is approached mortality may drop below 50%. Following maturity, mortality approaches (but never reaches) 0%. Therefore, of the original 375 seeds planted per sq.

ft., we might expect to yield 4 or 5 mature seed-producing plants per sq. ft. in two or three growing seasons following seeding (e.g., 375 seeds x 0.1 seed survival x 0.25 seedling survival x 0.5 adult plant survival). On some sites these figures are optimistic, on others they may even be misleading, but in general they reflect our overall experiences in the New World over the last 22 years.

7. Revegetation-restoration should be scheduled for and accomplished in the fall of the year. Even though we collected data in 1994 that may appear to refute this general rule, we are reluctant to alter many years of success based on a single year's data. Fall season planting and seeding appears to be successful most of the time because:

    a. Fall coincides with the period when native plant species mature and disperse their seeds.

    b. Fall timing ensures that seed will be in-place during the winter in order to meet potential dormancy requirements.

    c. Seeds will be in-place during winter snowfall.

    d. Seeds will be in-place during spring snowmelt when conditions are ideal for germination, seedling emergence, and seedling growth.

8. Seeding should be accomplished by broadcasting rather than by drilling or other mechanical means. Native seed are highly variable in shape, size, mass, and surface characteristics, hence tend not to be well suited to mechanical devises developed for more uniform agricultural-type crop plants and propagules. Native seeds tend to become clogged in mechanical seeding devises, and tend to sort out in hoppers and other devises according to relative density, hence irregular patterns in seed distribution occur.

    Following seed application, the seed should be lightly raked to cover them with soil, and then packed to firm the seed into the soil fines. This step is critical to some species because it ensures hydraulic conductivity between the seeds and soil water, it minimizes seed drying due to exposure at the surface, and it protects the seed from redistribution by wind, water, and animals. Although some alpine species (e.g., sedges and rushes) are photoblastic (require light for germination), they can be applied on the surface in a separate operation following seeding of non-photoblastic species.

    Application of seed by hydromulching and hydroseeding techniques is not recommended in high elevation environments because of the limitations discussed above. Hydroseeding often covers the seed with fibrous mulching materials, but the hydraulic conductivity between these materials and the soil can be lost during high winds or severe drying conditions. The seeds may then become separated from the soil, and severe dehydration and subsequent mortality can result.

Mixtures of at least several different species and lifeforms (grasses, sedges, and forbs) are generally more successful than use of single species alone. This practice will enhance species diversity, and will be more compatible with natural succession. Mixtures of species are also less susceptible to complete annihilation by such natural phenomena as disease, insect outbreaks, drought, frost, and other natural catastrophes.

9. Apply surface mulch, such as erosion blankets, following seeding and planting. This material protects and stabilizes the surface, and promotes restoration, by:

   a. minimizing surface rilling and erosion due to rain drop impact and surface runoff.

   b. reduces evaporation of surface soil water.

   c. reduces wind erosion and redistribution of seed and soil fine particles.

   d. reduces the incidences of frost and other temperature extremes at the surface.

   e. increases snow and rain water trapping.

   f. appears to improve native seed trapping.

   Light to moderate rates of application are better than heavier application rates. The surface of the soil should be visible when viewed vertically through the fibers or other materials used. Erosion blanket materials provide about 2 tons per acre equivalent rates, and appear to be near ideal for most revegetation-stabilization work. Stapling, or otherwise securing, the mulch to the surface is essential. We recommend stapling a little more frequently than the rate recommended by the manufacturer, especially on steep unstable slopes where water and wind movement can occur freely under the blanket material. We have used blown straw secured in-place with liquified tackifiers, but these are far more cumbersome than commercially available erosion blankets.

10. Following installation, the site should be assessed yearly for several years to determine relative success or failure, and to re-apply amendments or seed in places requiring re-applications. Re-fertilization may be required to further accelerate successional development of revegetation areas and to enhance survival and establishment of invading outside species. In addition, periodic soil sampling and analyses is recommended to assess nutrient deficiencies, requirements for re-liming, and other amendments.

    Fencing may be required to minimize impacts by animals and people (some would argue about what group causes the most damage; in our experience people are far more destructive "animals" than most animals). Sometimes signing only advertises where the most sensitive areas are located, and increases the chances of interference and destruction by "animals"!

## LITERATURE CITED


Amacher, M. C., R. W. Brown, J. Kotuby-Amacher, and A. Willis. 1993. Adding sodium hydroxide to study metal removal in a stream affected by acid mine drainage. USDA Forest Service, Intermountain Research Station. Research Paper INT-465. Ogden, Ut. 17 p.

Barber, S. A. 1984. Liming materials and practices. p. 171-209. *In*: F. Adams (ed.). Soil Acidity and Liming, Second Edition. No. 12, Agronomy. Amer. Soc. Agron., Madison, WI.

Brown, R. W. and J. C. Chambers. 1990. Reclamation practices in high-mountain ecosystems. p. 329-334. *In*: Proceedings: Symposium on Whitebark Pine Ecosystems: Ecology and Management. USDA Forest Service, Intermountain Research Station. General Technical Report INT-270. Ogden, Utah.

Brown, R. W., J. C. Chambers, R. M. Wheeler, E. E. Neely, and M. I. Kelrick. 1988. Adaptations of *Deschampsia caespitosa* (tufted hairgrass) for revegetation of high elevation disturbances: some selection criteria. p. 147-172. *In*: Proceedings: High Altitude Revegetation Workshop No. 8. Colorado Water Resources Research Institute, Info. Series No. 59. Colo. State Univ., Fort Collins.

Brown, R. W. and R. S. Johnston. 1976. Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana. USDA Forest Service, Intermountain Research Station. Research Note INT-206. 8 p.

Brown, R. W. and R. S. Johnston. 1978. Rehabilitation of high elevation mine disturbances. p. 116-130. *In*: Proceedings: High Altitude Revegetation Workshop No. 3. Colorado Water Resources Research Institute, Info. Series No. 28. Colo. State Univ., Fort Collins.

Brown, R. W. and R. S. Johnston. 1979. Revegetation of disturbed alpine rangelands. p.76-94. *In*: Special Management Needs of Alpine Ecosystems. Soc. for Range Management. Denver, CO.

Brown, R. W. and R. S. Johnston. 1980. An assessment of revegetation techniques for alpine disturbances. p. 126-146. *In*: Proceedings: High Altitude Revegetation Workshop No. 4. Colorado Water Resources Research Institute, Info. Series No. 42. Colo. State Univ., Fort Collins.

Brown, R. W., R. S. Johnston, and J. C. Chambers. 1984. Responses of seeded grasses to repeated fertilization applications on acidic alpine mine spoils. p. 200-214. *In*: Proceedings: High Altitude Revegetation Workshop No. 6. Colorado Water Resources Research Institute, Info. Series No. 53. Colo. State Univ., Fort Collins.

Brown, R. W., R. S. Johnston, and K. Van Cleve. 1978. Rehabilitation problems in alpine and arctic regions. p. 23-44. *In*: Reclamation of Drastically Disturbed Lands. Amer. Soc. Agron., Madison, WI.

Haggas, L., R. W. Brown, and R. S. Johnston. 1987. Light requirement for seed germination of Payson sedge. J. Range Manage. 40:180-184.

Johnston, R. S., R. W. Brown, and J. Cravens. 1975. Acid mine rehabilitation problems at high elevations. p. 66-79. *In*: Watershed Management Symposium, Amer. Soc. Civil Engineers, Irrigation and Drainage Div. Logan, UT.

Simonin, H. A. 1988. Neutralization of acidic waters. Environ. Sci. Technol. 22(10): 1143-1145.

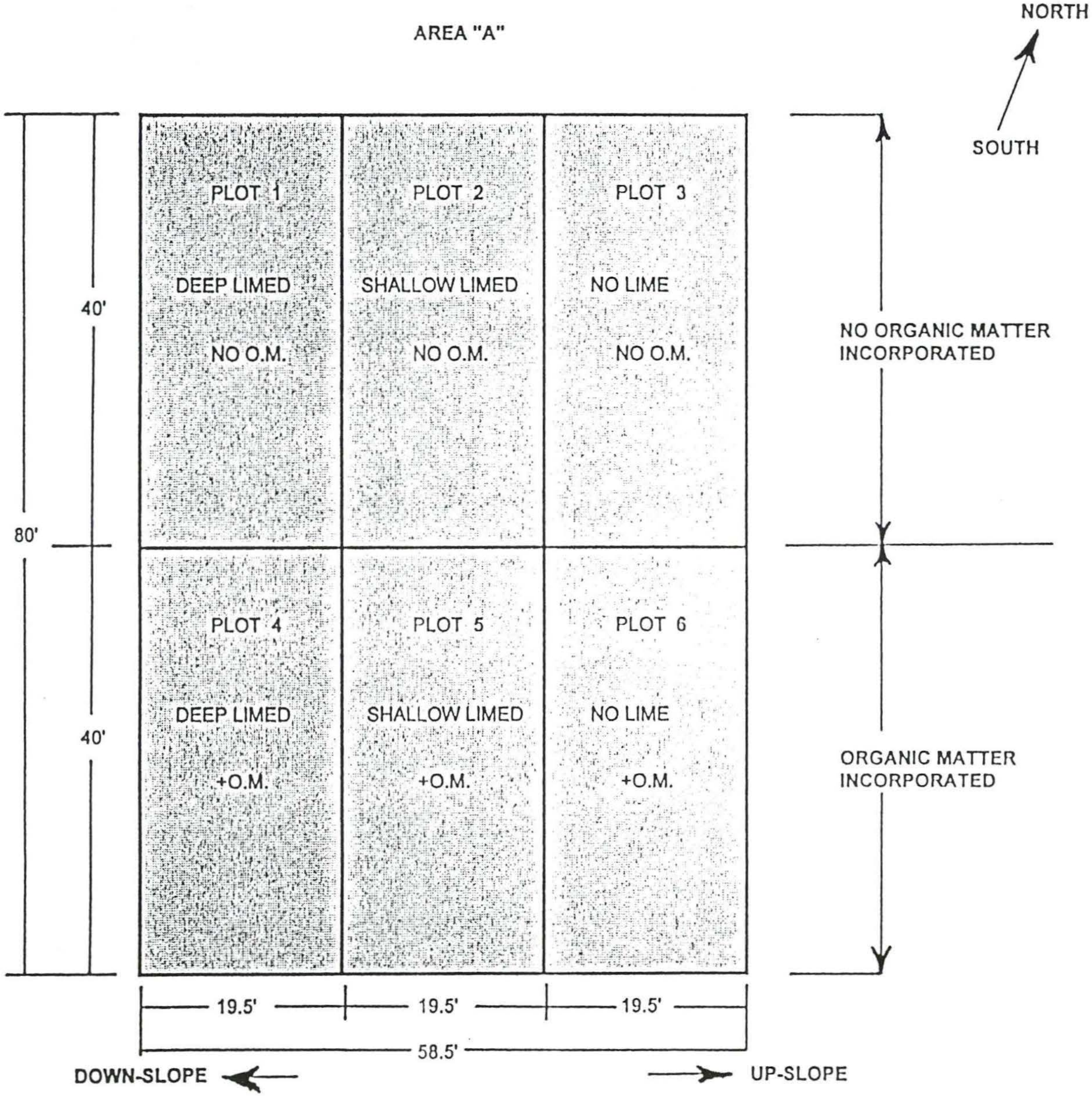
Sorensen, D. L., W. A. Kneib, D. B. Porcella, and B. Z. Richardson. 1980. Determining the lime requirement for the Blackbird Mine spoil. J. Environ. Qual. 9(1):162-166.

Thomas, G. W. and Hargrove, W. L. 1984. The chemistry of soil acidity. p. 3-56. *In*: F. Adams (ed.). Soil Acidity and Liming, Second Edition. No. 12, Agronomy. Amer. Soc. Agron., Madison, WI.

# APPENDIX 1:

## PLOT LAYOUT MAPS

## McLAREN MINE: 1993 DEEP-LIME SEEDED PLOTS



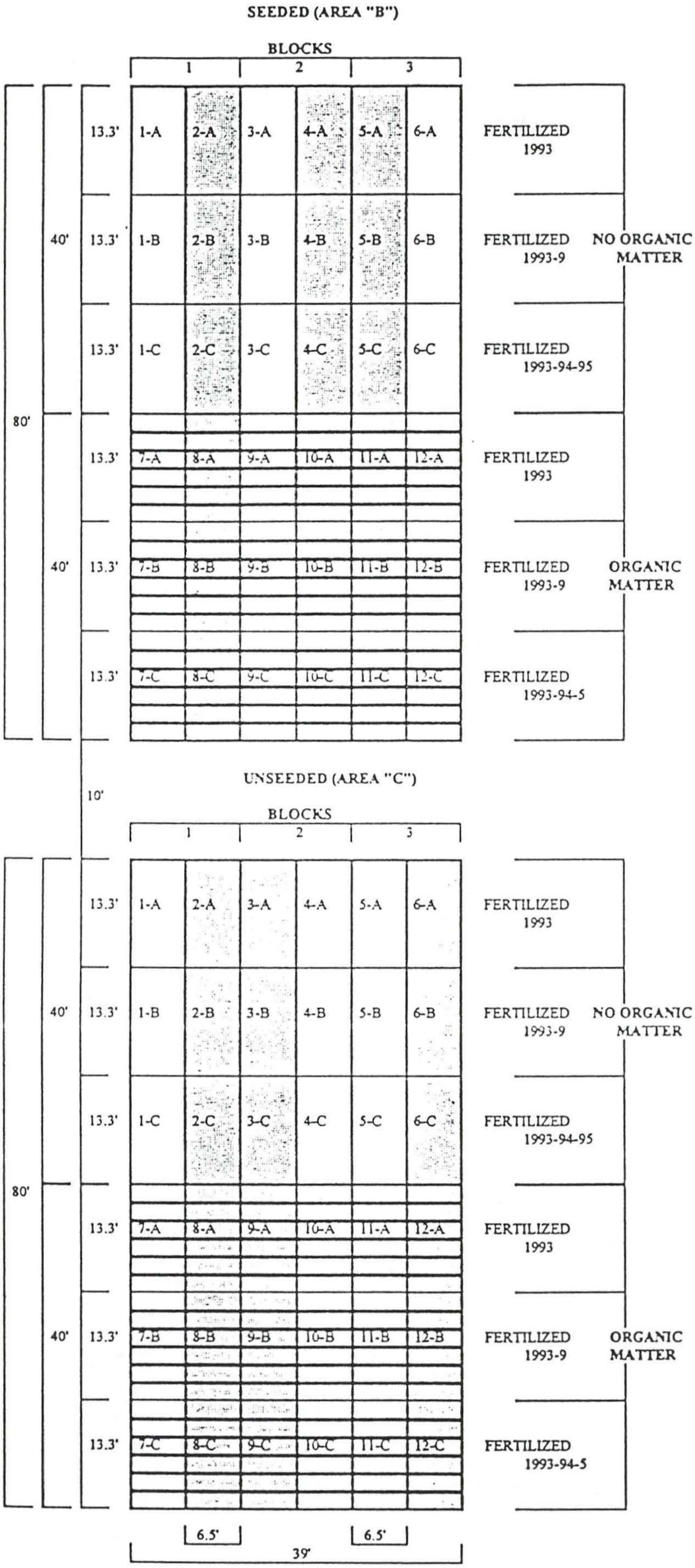

**PLOT LAYOUT DETAILS:**

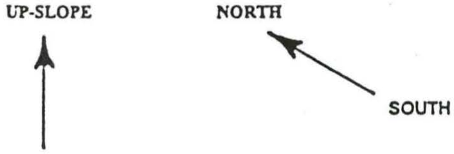
1. Established September 1993
2. Amendments applied 1993
   - -hydrated lime
     - deep limed plots = 45.4 tons/ac
     - shallow limed plots = 11.4 tons/ac
     - unlimed plots = 0 tons/ac
   - -fertilizer 1993
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - -organic matter (peat moss)
     - south half of each plot only at 3909 lbs/ac
   - -surface mulch (North Amer. Green) erosion blanket S-150 entire area
3. Seeding rates and species composition:

| | lbs/ac |
|---|---|
| *Agropyron trachycaulum* | 18.41 |
| *Deschampsia caespitosa* | 2.16 |
| *Phleum alpinum* | 3.14 |
| *Poa alpina* | 2.29 |
| *Trisetum spicatum* | 1.54 |
| TOTAL | 27.54 |

4. Refertilization 1994-95
   - 31-4-4 at 100 lbs N/ac
   - P2O5 at 13 lbs/ac
   - K2O at 13 lbs/ac

# MCLAREN MINE: 1993 SPRING SEEDED AND UNSEEDED PLOTS



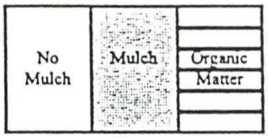




PLOT LAYOUT DETAILS

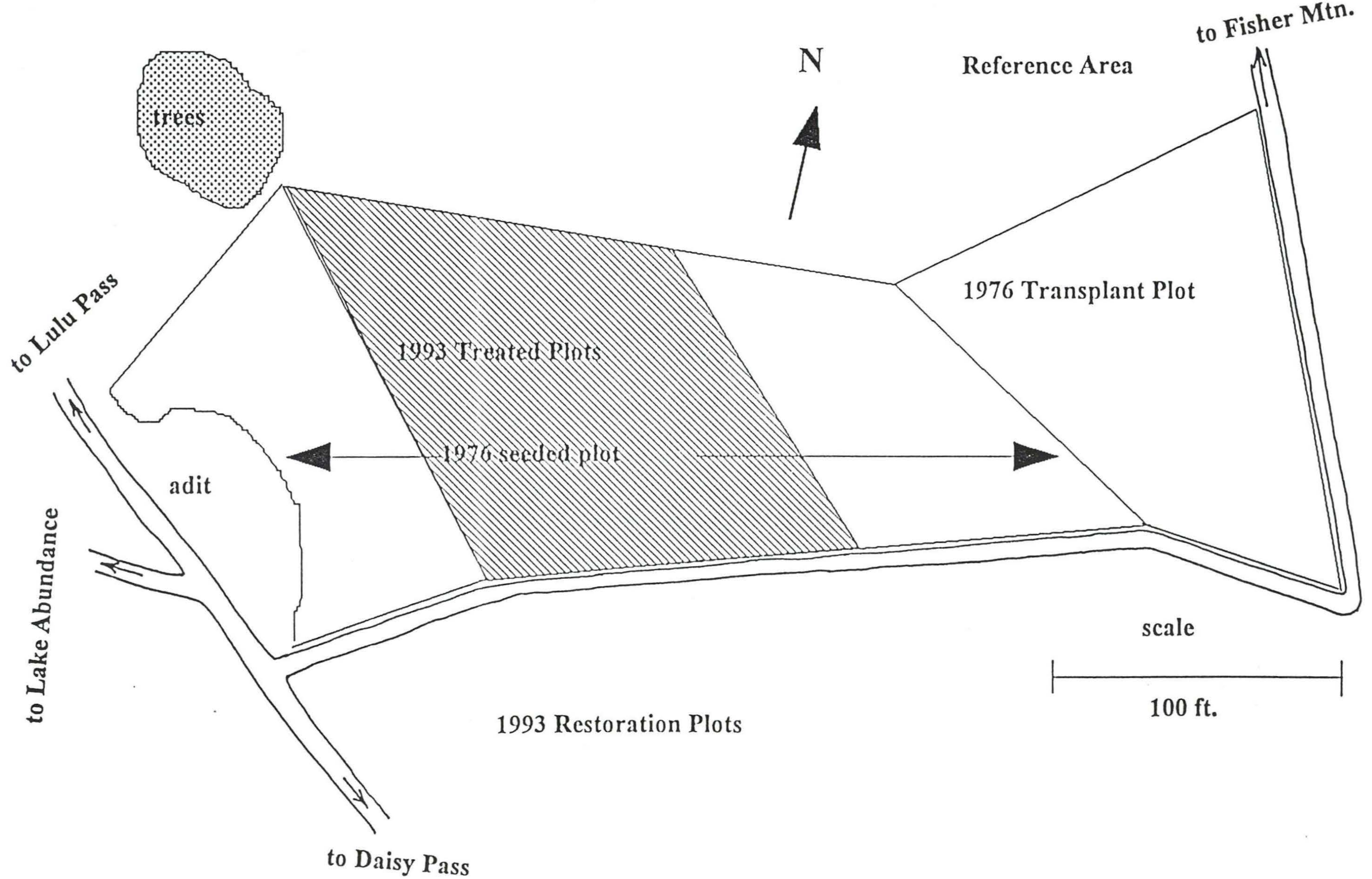
1. Established: July 1993
2. Amendments:
   - -hydrated lime: 1.4 tons/ac
   - -fertilizer 1993:
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - -refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O5 at 13 lbs/ac
3. Mulch: North American Green erosion blanket (S-150)
4. Organic matter: (lower half of area only): peat moss at 5864 lbs/ac
5. Seeding rates and species used:

| | lbs/ac |
|---|---|
| *Agropyron trachycalum* | 18.41 |
| *Deschampsia caespitosa* | 2.16 |
| *Phleum alpinum* | 3.14 |
| *Poa alpina* | 2.29 |
| *Trisetum spicatum* | 1.54 |
| TOTAL | 27.54 |

LEGEND

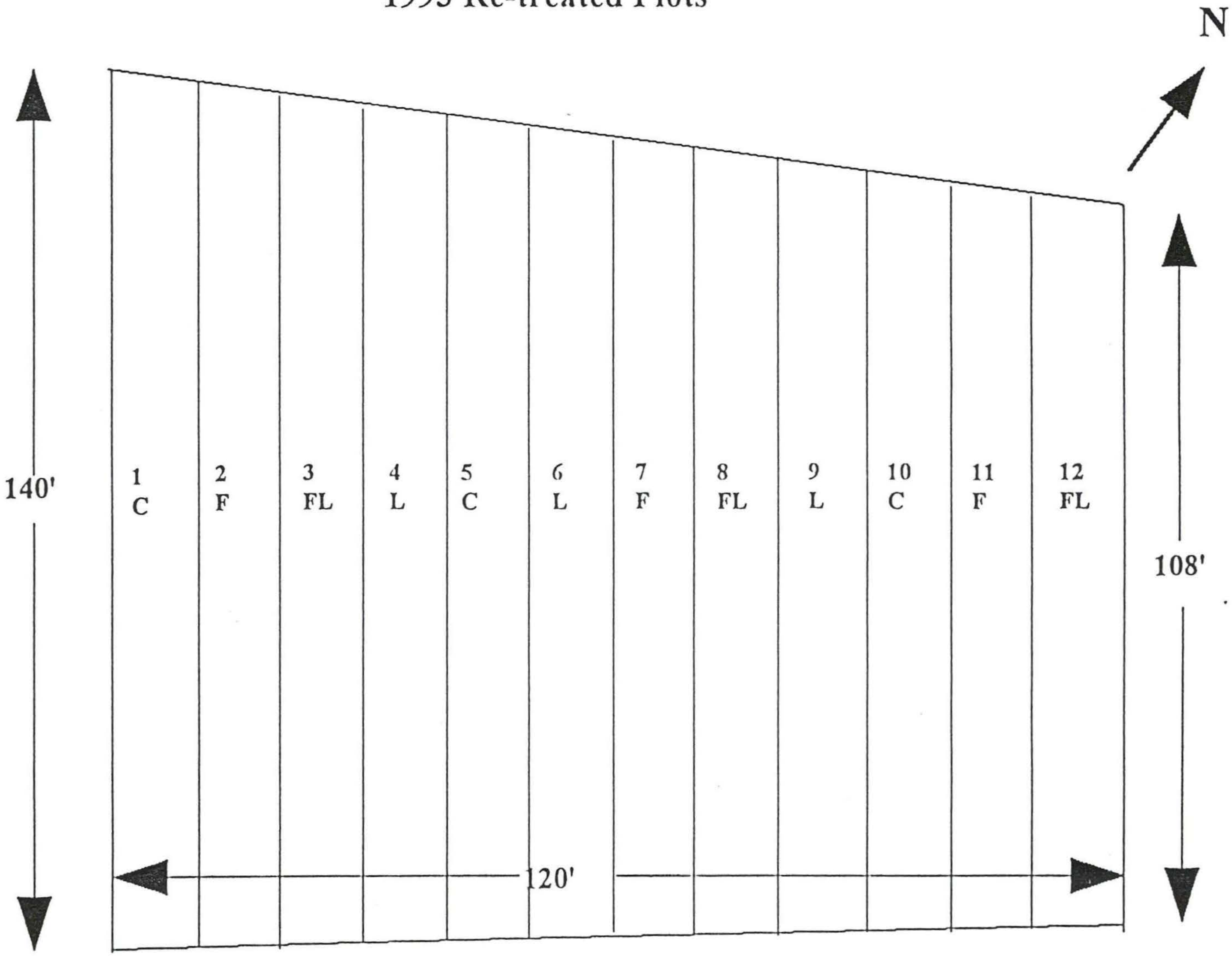



# McLAREN MINE DEMONSTRATION AREA

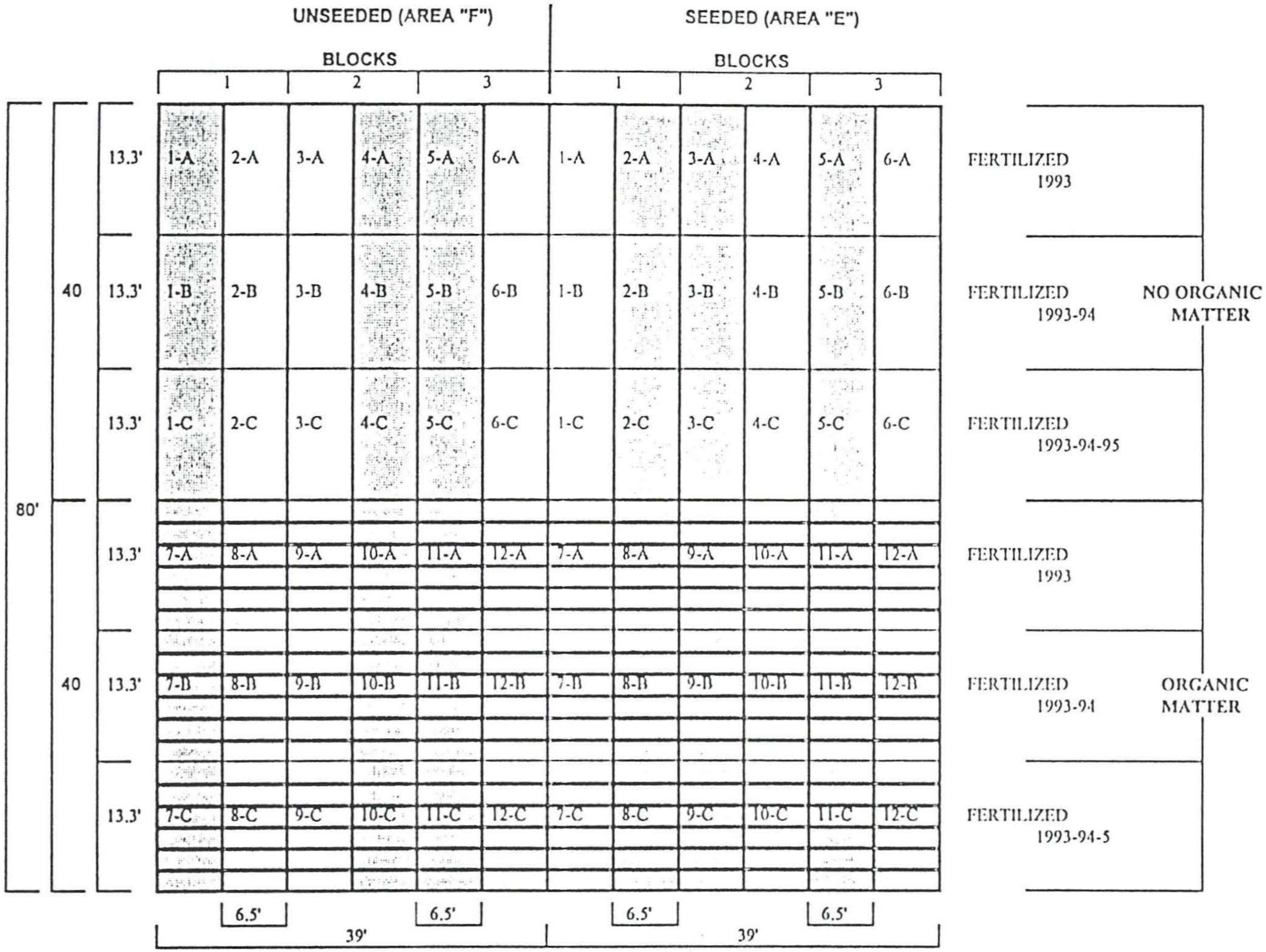


# McLAREN MINE DEMONSTRATION AREA

## 1993 Re-treated Plots



# MCLAREN MINE: 1993 FALL SEEDED AND UNSEEDED PLOTS




UP-SLOPE

NORTH

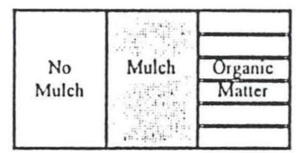
SOUTH

**PLOT LAYOUT DETAILS**

1. Established: September 1993
2. Amendments:
   - -hydrated lime: 7.1 tons/ac
   - -fertilizer 1993:
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - -refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O5 at 13 lbs/ac
3. Mulch: North American Green erosion blanket (S-150)
4. Organic matter: (lower half of area only): peat moss at 5864 lbs/ac
5. Seeding rates and species used:

| | lbs/ac |
|---|---|
| *Agropyron trachycalum* | 18.41 |
| *Deschampsia caespitosa* | 2.16 |
| *Phleum alpinum* | 3.14 |
| *Poa alpina* | 2.29 |
| *Trisetum spicatum* | 1.54 |
| TOTAL | 27.54 |

**LEGEND**




DOWN-SLOPE

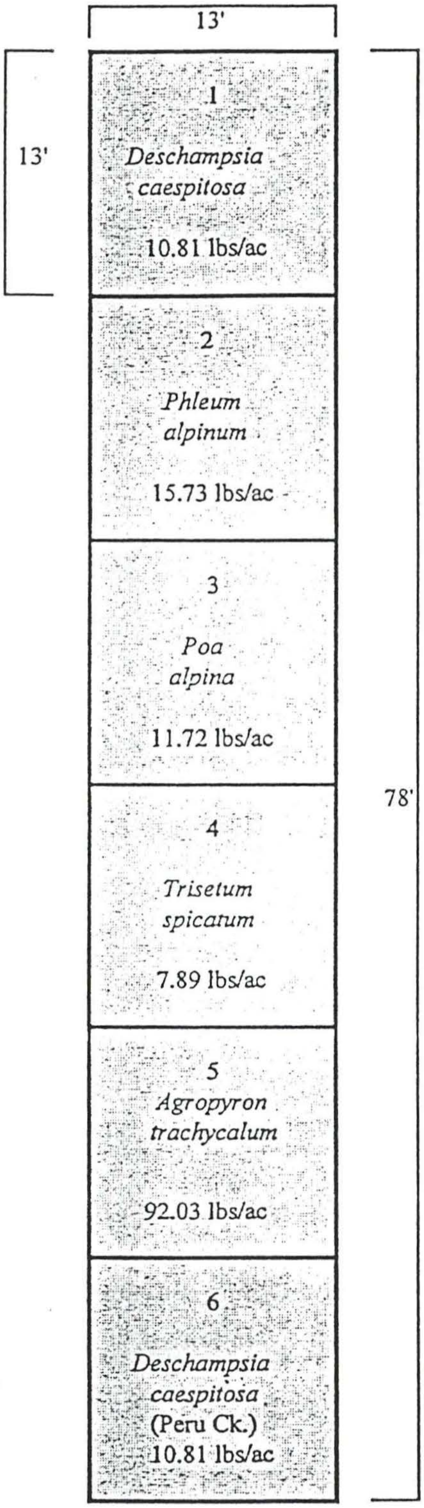
# MCLAREN MINE: 1993 SINGLE-SPECIES SEEDED PLOTS

AREA "G"

NORTH

SOUTH

UP-SLOPE



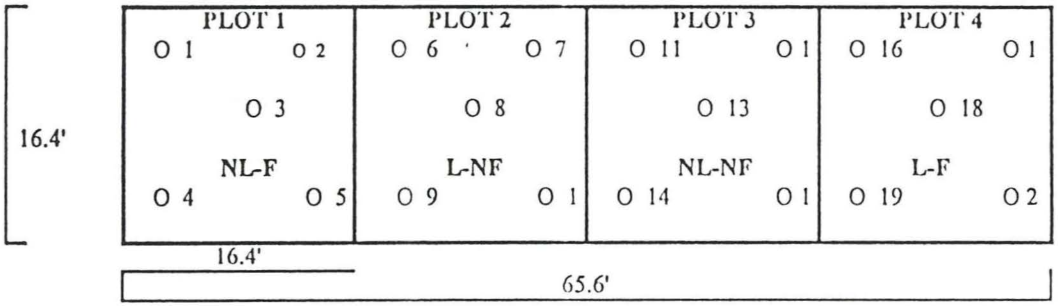

DOWN-SLOPE

## PLOT LAYOUT DETAILS

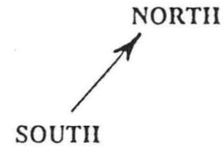
1. Established September 1993
2. Amendments applied in 1993:
   - -hydrated lime: 11.4 tons/ac
   - -fertilizer
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - - mulch: North Amer. Green erosion blanket S-150 (entire plot area)
   - -organic matter: peat moss at 6014 lbs/ac
3. Refertilization 1994-95
   - 31-4-4 at 100 lbs N/ac
   - P2O5 at 13 lbs/ac
   - K2O at 13 lbs/ac

# TRANSPLANT PLOTS: 1993 GLENGARY AND MCLAREN MINE AREAS

## GLENGARY ADIT: 1993 TRANSPLANT PLOTS
Carex paysonis
AREA "P"

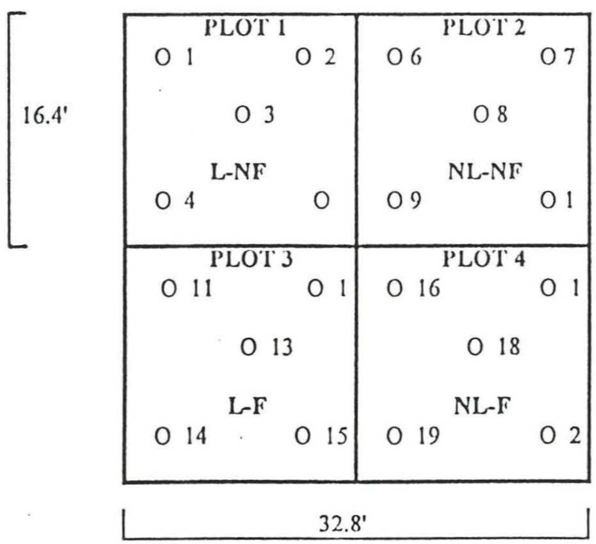


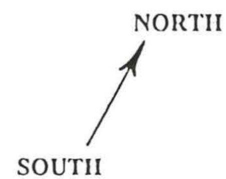

"O" = locations of each transplant and plant number

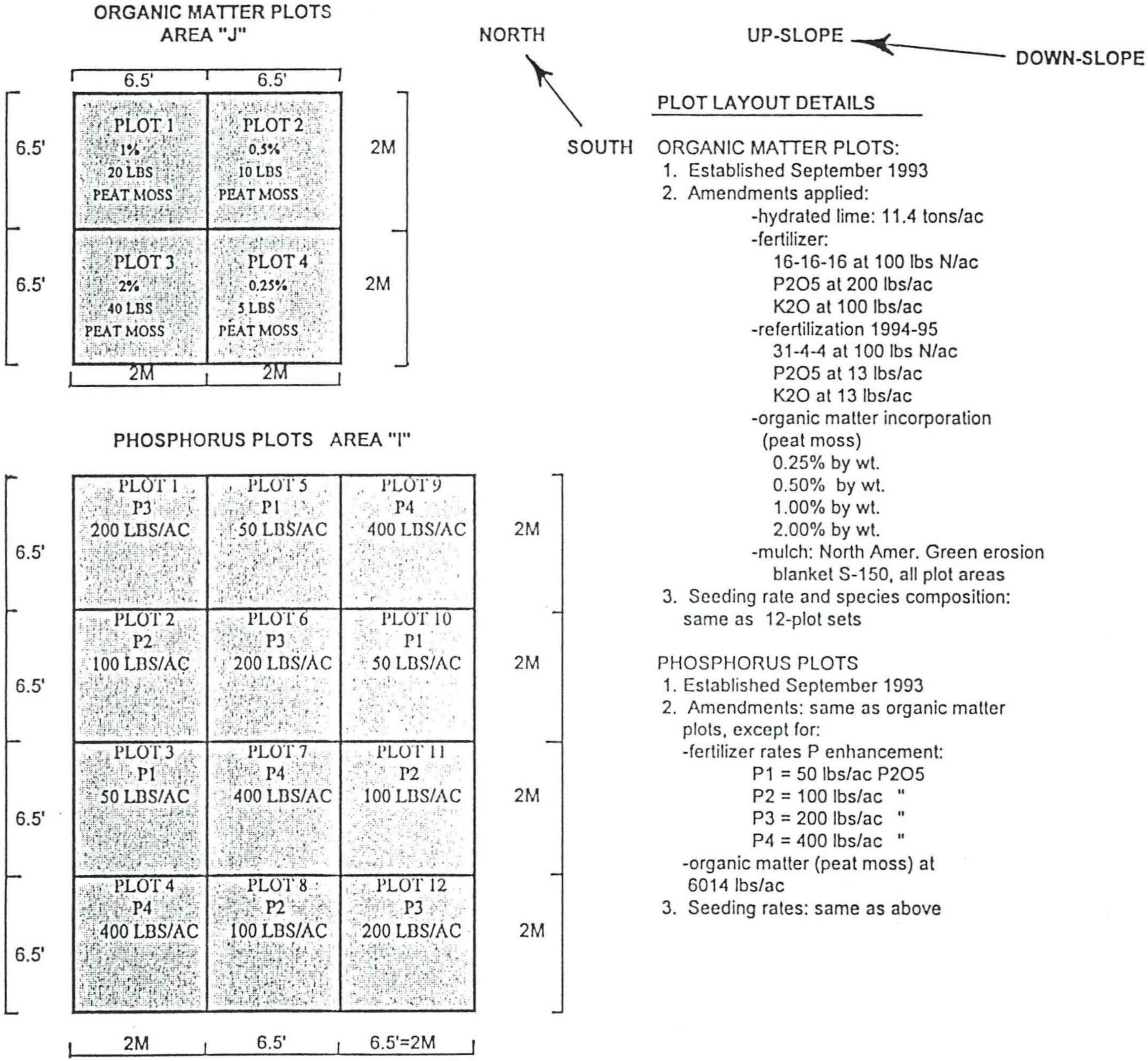

**PLOT LAYOUT DETAILS**
both areas:
1. established September 1993
2. amendments applied:
   - -hydrated lime:
     17 tons/ac (Glengary)
     11.4 tons/ac (McLaren Mine)
   - -fertilizer: both areas
     16-16-16 at 100 lbs N/ac
     P2O5 at 200 lbs/ac
     K2O at 100 lbs/ac
   - -refertilization 1994-95
     31-4-4 at 100 lbs N/ac
     P2O5 at 13 lbs/ac
     K2O at 13 lbs/ac
   - -mulch: none
   - -organic matter incorporated: none
3. transplants: pads of Carex paysonis
   planted August 1994

## McLAREN MINE: 1993 TRANSPLANT PLOTS
Carex paysonis
AREA "H"




# McLAREN MINE: 1993 ORGANIC MATTER AND PHOSPHORUS SEEDED PLOTS




PLOT LAYOUT DETAILS

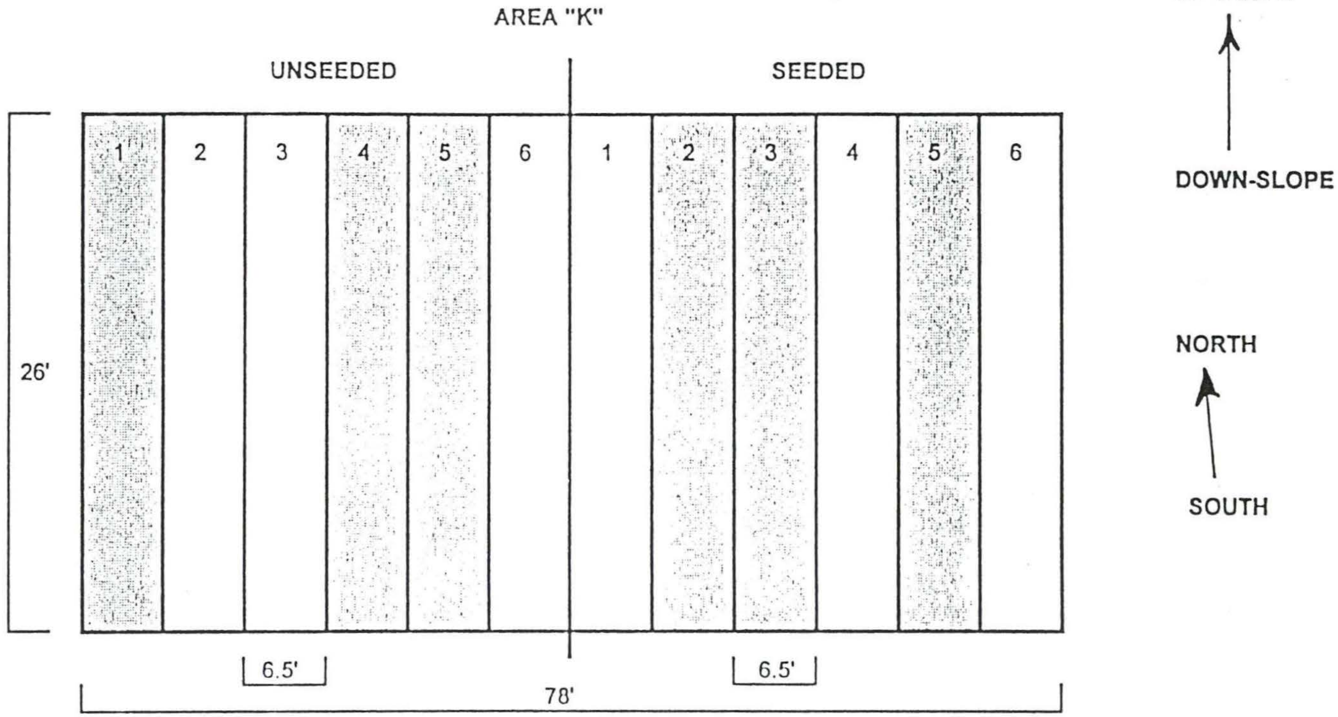
ORGANIC MATTER PLOTS:

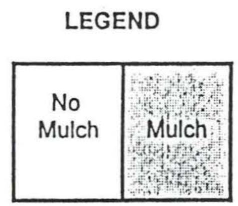
1. Established September 1993
2. Amendments applied:
   - -hydrated lime: 11.4 tons/ac
   - -fertilizer:
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - -refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O at 13 lbs/ac
   - -organic matter incorporation (peat moss)
     - 0.25% by wt.
     - 0.50% by wt.
     - 1.00% by wt.
     - 2.00% by wt.
   - -mulch: North Amer. Green erosion blanket S-150, all plot areas
3. Seeding rate and species composition: same as 12-plot sets

PHOSPHORUS PLOTS

1. Established September 1993
2. Amendments: same as organic matter plots, except for:
   - -fertilizer rates P enhancement:
     - P1 = 50 lbs/ac P2O5
     - P2 = 100 lbs/ac "
     - P3 = 200 lbs/ac "
     - P4 = 400 lbs/ac "
   - -organic matter (peat moss) at 6014 lbs/ac
3. Seeding rates: same as above

# FISHER MTN. 1993 ROAD-CUT SEEDED PLOTS

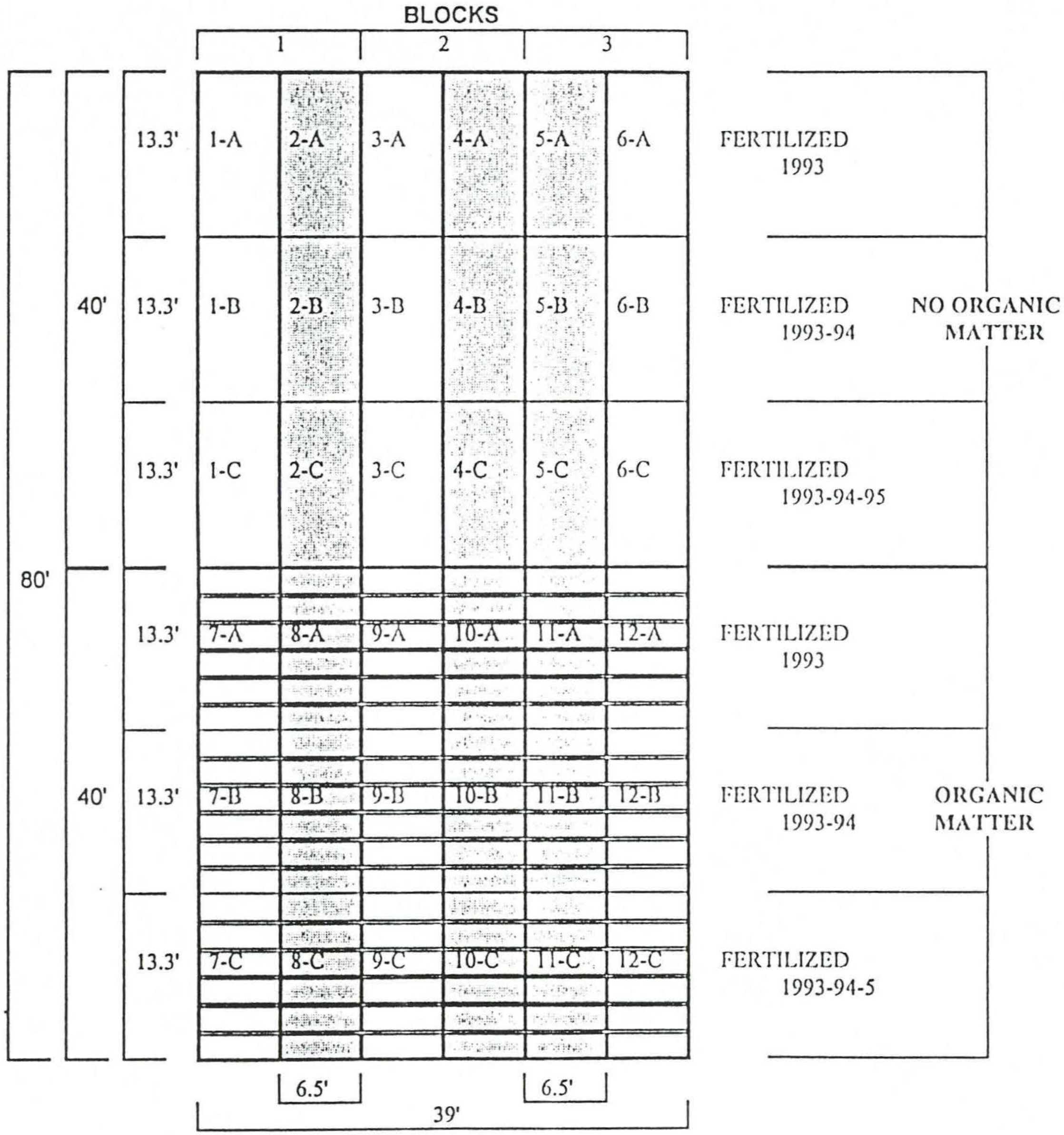



PLOT LAYOUT DETAILS:

1. Established September 1993
2. Amendments applied to all plots:
   - -hydrated lime at 2.8 tons/ac (seeded and unseeded areas)
   - -fertilizer 1993
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 100 lbs/ac
     - K2O at 100 lbs/ac
   - -refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O at 13 lbs/ac
   - -no organic matter incorporated
   - -surface mulch: North Amer. Green
     S-150 erosion blanket (shaded areas)
3. Seeding rate and species composition
   - -same as 12-set plots

# GLENGARY ADIT: 1993 SPRING SEEDED PLOTS




UP-SLOPE

NORTH

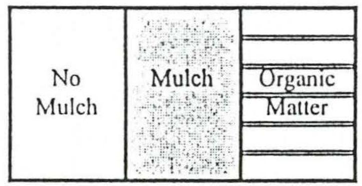
SOUTH

## PLOT LAYOUT DETAILS

1. Established: July 1993
2. Amendments:
   - hydrated lime: 7.1 tons/ac
   - fertilizer 1993:
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O5 at 13 lbs/ac
3. Mulch: North American Green erosion blanket (S-150)
4. Organic matter: (lower half of area only): peat moss at 5864 lbs/ac
5. Seeding rates and species used:

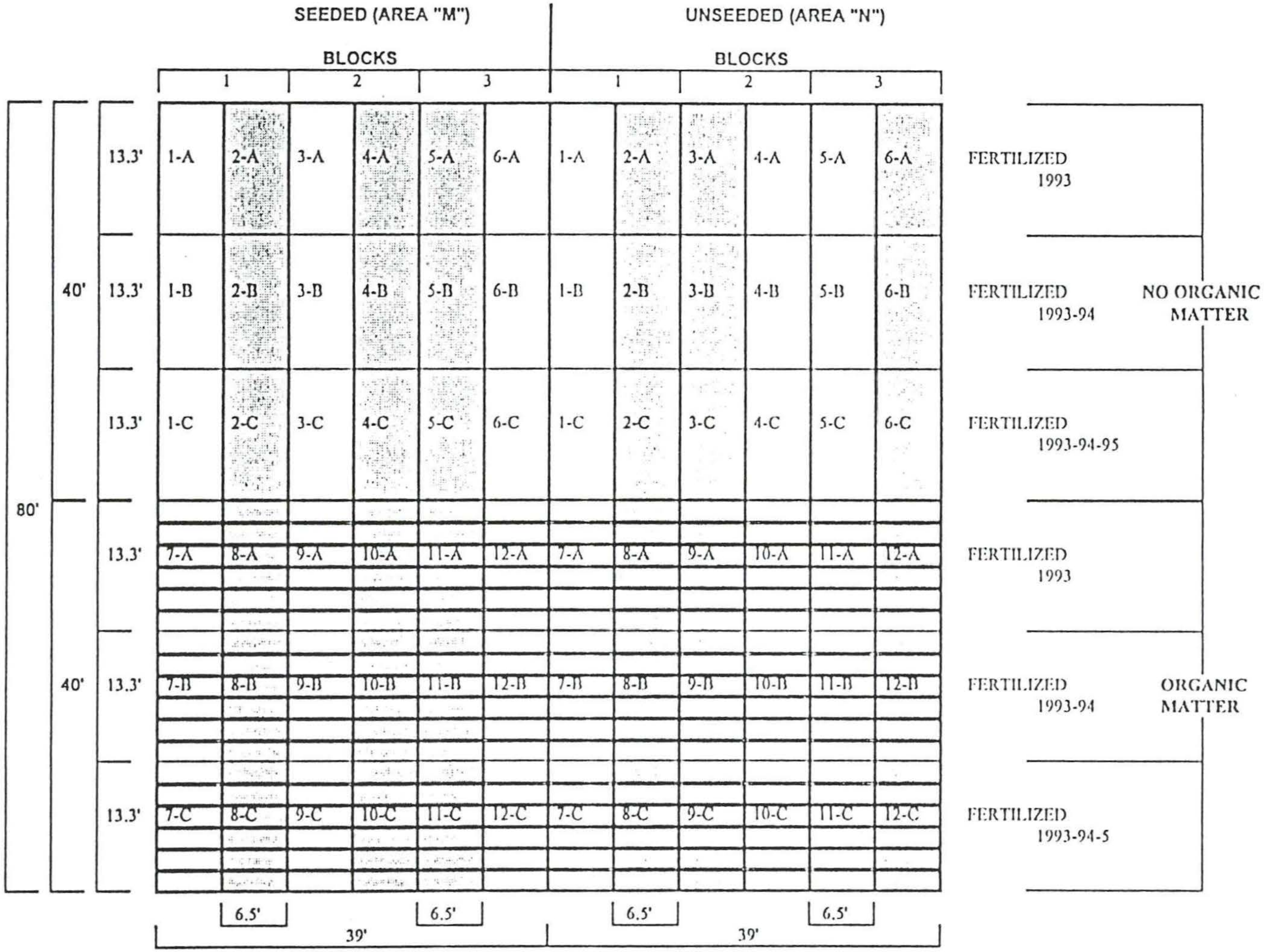
| Species | lbs/ac |
|---|---|
| *Agropyron trachycalum* | 18.41 |
| *Deschampsia caespitosa* | 2.16 |
| *Phleum alpinum* | 3.14 |
| *Poa alpina* | 2.29 |
| *Trisetum spicatum* | 1.54 |
| TOTAL | 27.54 |

### LEGEND




DOWN-SLOPE

# GLENGARY ADIT: 1993 FALL SEEDED AND UNSEEDED PLOTS




UP-SLOPE

NORTH

SOUTH

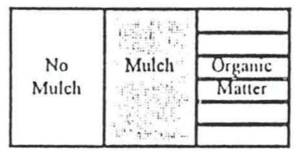
DOWN-SLOPE

## PLOT LAYOUT DETAILS

1. Established: September 1993
2. Amendments:
   - -hydrated lime: 17.0 tons/ac
   - -fertilizer 1993:
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - -refertilization 1994-95
     - 31-4-4 at 100 lbs N/ac
     - P2O5 at 13 lbs/ac
     - K2O5 at 13 lbs/ac
3. Mulch: North American Green erosion blanket (S-150)
4. Organic matter: (lower half of area only): peat moss at 5864 lbs/ac
5. Seeding rates and species used:

| | lbs/ac |
|---|---|
| *Agropyron trachycalum* | 18.41 |
| *Deschampsia caespitosa* | 2.16 |
| *Phleum alpinum* | 3.14 |
| *Poa alpina* | 2.29 |
| *Trisetum spicatum* | 1.54 |
| TOTAL | 27.54 |

LEGEND



# GLENGARY ADIT: 1993 SINGLE-SPECIES SEEDED PLOTS

AREA "O"

13' × 13' plots; total length 78'

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| *Deschampsia caespitosa* | *Phleum alpinum* | *Poa alpina* | *Trisetum spicatum* | *Agropyron trachycalum* | *Deschampsia caespitosa (Peru Ck.)* |
| 10.81 lbs/ac | 15.73 lbs/ac | 11.72 lbs/ac | 7.89 lbs/ac | 92.03 lbs/ac | 10.81 lbs/ac |

NORTH

SOUTH

UP-SLOPE

DOWN-SLOPE

## PLOT LAYOUT DETAILS

1. Established September 1993
2. Amendments applied in 1993:
   - -hydrated lime: 17.0 tons/ac
   - -fertilizer
     - 16-16-16 at 100 lbs N/ac
     - P2O5 at 200 lbs/ac
     - K2O at 100 lbs/ac
   - - mulch: North Amer. Green erosion blanket S-150 (entire plot area)
   - -organic matter: peat moss at 5864 lbs/ac
3. Refertilization 1994-95
   - 31-4-4 at 100 lbs N/ac
   - P2O5 at 13 lbs/ac
   - K2O at 13 lbs/ac

## APPENDIX 2:

## SPECIFICATIONS FOR AMENDMENT APPLICATIONS

| Tables | Page |
|---|---|

Lime and Fertilizer Amounts for McLaren Mine Demo Plots

| | | Average | | | | Lime | Fertilizer | Lime | Fertilizer |
|---|---|---|---|---|---|---|---|---|---|
| Plot No. | Treatment | Length | Width | Area | Area | Rate | Rate | Amount | Amount |
| | | ft | ft | sq ft | A | T/A | lbs/A | lbs | lbs |
| | | | | | | | | | |
| 1 | Control | 138.5 | 10 | 1385 | 0.0318 | | | | |
| 2 | Fertilizer | 135.5 | 10 | 1355 | 0.0311 | | 625 | | 19.4 |
| 3 | Fertilizer + Lime | 132.5 | 10 | 1325 | 0.0304 | 2 | 625 | 122 | 19.0 |
| 4 | Lime | 129.5 | 10 | 1295 | 0.0297 | 2 | | 119 | |
| 5 | Control | 126.5 | 10 | 1265 | 0.0290 | | | | |
| 6 | Lime | 124 | 10 | 1240 | 0.0285 | 2 | | 114 | |
| 7 | Fertilizer | 121.5 | 10 | 1215 | 0.0279 | | 625 | | 17.4 |
| 8 | Fertilizer + Lime | 118.5 | 10 | 1185 | 0.0272 | 2 | 625 | 109 | 17.0 |
| 9 | Lime | 116 | 10 | 1160 | 0.0266 | 2 | | 107 | |
| 10 | Control | 114 | 10 | 1140 | 0.0262 | | | | |
| 11 | Fertilizer | 111.5 | 10 | 1115 | 0.0256 | | 625 | | 16.0 |
| 12 | Fertilizer + Lime | 109 | 10 | 1090 | 0.0250 | 2 | 625 | 100 | 15.6 |

1993 New World Project Reclamation Plots
Lime Treatments

| Location | Width ft | Length ft | Area sq ft | Area acres | $CaCO_3$ Rate T/A | $Ca(OH)_2$ Rate T/A | $Ca(OH)_2$ Amount tons | $Ca(OH)_2$ Amount lbs | Calculated $Ca(OH)_2$ Amount 50 lb bags | Actual $Ca(OH)_2$ Amount 50 lb bags |
|---|---|---|---|---|---|---|---|---|---|---|
| McLaren Mine | | | | | | | | | | |
| Spring seeded | 39 | 80 | 3120 | 0.07163 | 2 | 1.4 | 0.102 | 203 | 4.1 | 5 |
| Spring unseeded | 39 | 80 | 3120 | 0.07163 | 2 | 1.4 | 0.102 | 203 | 4.1 | 5 |
| Fall seeded | 39 | 80 | 3120 | 0.07163 | 10 | 7.1 | 0.509 | 1017 | 20.3 | 21 |
| Fall unseeded | 39 | 80 | 3120 | 0.07163 | 10 | 7.1 | 0.509 | 1017 | 20.3 | 21 |
| Single species | 13 | 78 | 1014 | 0.02328 | 16 | 11.4 | 0.264 | 529 | 10.6 | 10 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 16 | 11.4 | 0.140 | 281 | 5.6 | 6 |
| P rates | 19.5 | 26 | 507 | 0.01164 | 16 | 11.4 | 0.132 | 264 | 5.3 | 5 |
| OM rates | 13 | 13 | 169 | 0.00388 | 16 | 11.4 | 0.044 | 88 | 1.8 | 2 |
| Deep lime | 19.5 | 80 | 1560 | 0.03581 | 64 | 45.4 | 1.627 | 3255 | 65.1 | 64 |
| Shallow lime | 19.5 | 80 | 1560 | 0.03581 | 16 | 11.4 | 0.407 | 814 | 16.3 | 16 |
| No lime | 19.5 | 80 | 1560 | 0.03581 | 0 | 0.0 | 0.000 | 0 | 0.0 | 0 |
| Total | | | 19388 | 0.44509 | | | 3.836 | 7671 | 153.4 | 155 |
| Glengarry Mine | | | | | | | | | | |
| Spring seeded | 39 | 80 | 3120 | 0.07163 | 10 | 7.1 | 0.509 | 1017 | 20.3 | 21 |
| Fall seeded | 39 | 80 | 3120 | 0.07163 | 24 | 17.0 | 1.220 | 2441 | 48.8 | 48 |
| Fall unseeded | 39 | 80 | 3120 | 0.07163 | 24 | 17.0 | 1.220 | 2441 | 48.8 | 48 |
| Single species | 13 | 78 | 1014 | 0.02328 | 24 | 17.0 | 0.397 | 793 | 15.9 | 16 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 24 | 17.0 | 0.210 | 421 | 8.4 | 8 |
| Total | | | 10912 | 0.25050 | | | 3.557 | 7113 | 142.3 | 141 |
| Fisher Mountain Road | | | | | | | | | | |
| Seeded | 39 | 26 | 1014 | 0.02328 | 4 | 2.8 | 0.066 | 132 | 2.6 | 4 |
| Unseeded | 39 | 26 | 1014 | 0.02328 | 4 | 2.8 | 0.066 | 132 | 2.6 | 4 |
| Total | | | 2028 | 0.04656 | | | 0.132 | 264 | 5.3 | 8 |
| Total | | | 32328 | 0.74215 | | | 7.525 | 15049 | 301.0 | 304 |

1993 New World Project Reclamation Plots
Organic Matter (OM) Treatments
1 bale peat moss = 4 cf = 70 lbs

| Location | Width ft | Length ft | Area sq ft | Area acres | OM Rate % | OM Rate lbs/A | Calculated OM Amount lbs | Calculated OM Amount Bales | Actual OM Amount Bales | Actual OM Amount lbs | Actual OM Rate lbs/A | Actual OM Rate % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| McLaren Mine | | | | | | | | | | | | |
| Spring seeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Spring unseeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Fall seeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Fall unseeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Single species | 13 | 78 | 1014 | 0.02328 | 0.25 | 5000 | 116 | 1.7 | 2 | 140 | 6014 | 0.30 |
| P rates | 19.5 | 26 | 507 | 0.01164 | 0.25 | 5000 | 58 | 0.8 | 1 | 70 | 6014 | 0.30 |
| Total | | | 7761 | 0.17817 | | | 891 | 12.7 | 15 | 1050 | | |
| OM rates | | | | | | | | | | | | |
| 0.25 % | 6.5 | 6.5 | 42 | 0.00097 | 0.25 | 5000 | 4.8 | 0.07 | | 4.8 | 5000 | 0.25 |
| 0.5 % | 6.5 | 6.5 | 42 | 0.00097 | 0.5 | 10000 | 9.7 | 0.14 | | 9.7 | 10000 | 0.50 |
| 1.0 % | 6.5 | 6.5 | 42 | 0.00097 | 1.0 | 20000 | 19.4 | 0.28 | | 19.4 | 20000 | 1.00 |
| 2.0 % | 6.5 | 6.5 | 42 | 0.00097 | 2.0 | 40000 | 38.8 | 0.55 | | 38.8 | 40000 | 2.00 |
| Total | | | 169 | 0.00388 | | | 72.7 | 1.04 | 1 | 72.7 | | |
| Deep lime | 19.5 | 40 | 780 | 0.01791 | 0.25 | 5000 | 90 | 1.3 | 1 | 70 | 3909 | 0.20 |
| Shallow lime | 19.5 | 40 | 780 | 0.01791 | 0.25 | 5000 | 90 | 1.3 | 1 | 70 | 3909 | 0.20 |
| No lime | 19.5 | 40 | 780 | 0.01791 | 0.25 | 5000 | 90 | 1.3 | 1 | 70 | 3909 | 0.20 |
| Total | | | 2340 | 0.05372 | | | 269 | 3.8 | 3 | 210 | | |
| Total | | | 10270 | 0.23577 | | | 1232 | 17.6 | 19 | 1333 | | |
| Glengarry Mine | | | | | | | | | | | | |
| Spring seeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Fall seeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Fall unseeded | 39 | 40 | 1560 | 0.03581 | 0.25 | 5000 | 179 | 2.6 | 3 | 210 | 5864 | 0.29 |
| Single species | 13 | 78 | 1014 | 0.02328 | 0.25 | 5000 | 116 | 1.7 | 2 | 140 | 6014 | 0.30 |
| Total | | | 5694 | 0.13072 | | | 654 | 9.3 | 11 | 770 | | |
| Total | | | 15964 | 0.36648 | | | 1886 | 26.9 | 30 | 2103 | | |

1993 New World Project Reclamation Plots
Fertilizer Treatments

| Location | Width ft | Length ft | Area sq ft | Area acres | N Rate lbs/A | P2O5 Rate lbs/A | K2O Rate lbs/A | 16-16-16 Rate lbs/A | 16-16-16 Amount lbs | 0-45-0 Rate lbs/A | 0-45-0 Amount lbs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| McLaren Mine | | | | | | | | | | | |
| Spring seeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Spring unseeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Fall seeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Fall unseeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Single species | 13 | 78 | 1014 | 0.02328 | 100 | 200 | 100 | 625 | 14.55 | 222 | 5.17 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 100 | 200 | 100 | 625 | 7.72 | 222 | 2.74 |
| OM rates | 13 | 13 | 169 | 0.00388 | 100 | 200 | 100 | 625 | 2.42 | 222 | 0.86 |
| Deep lime | 19.5 | 80 | 1560 | 0.03581 | 100 | 200 | 100 | 625 | 22.38 | 222 | 7.95 |
| Shallow lime | 19.5 | 80 | 1560 | 0.03581 | 100 | 200 | 100 | 625 | 22.38 | 222 | 7.95 |
| No lime | 19.5 | 80 | 1560 | 0.03581 | 100 | 200 | 100 | 625 | 22.38 | 222 | 7.95 |
| Total | | | 18881 | 0.43345 | | | | | 270.90 | | 96.23 |
| Glengarry Mine | | | | | | | | | | | |
| Spring seeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Fall seeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Fall unseeded | 39 | 80 | 3120 | 0.07163 | 100 | 200 | 100 | 625 | 44.77 | 222 | 15.90 |
| Single species | 13 | 78 | 1014 | 0.02328 | 100 | 200 | 100 | 625 | 14.55 | 222 | 5.17 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 100 | 200 | 100 | 625 | 7.72 | 222 | 2.74 |
| Total | | | 10912 | 0.25050 | | | | | 156.56 | | 55.61 |
| Fisher Mountain Road | | | | | | | | | | | |
| Seeded | 39 | 26 | 1014 | 0.02328 | 100 | 100 | 100 | 625 | 14.55 | | |
| Unseeded | 39 | 26 | 1014 | 0.02328 | 100 | 100 | 100 | 625 | 14.55 | | |
| Total | | | 2028 | 0.04656 | | | | | 29.10 | | |
| Total | | | 31821 | 0.73051 | | | | | 456.57 | | 151.84 |

1993 New World Project Reclamation Plots
Fertilizer Treatments for P Plots

| Plot No. | Width ft | Length ft | Area sq ft | Area acres | N Rate lbs/A | 46-0-0 Rate lbs/A | 46-0-0 Amount lbs | P2O5 Rate lbs/A | 0-45-0 Rate lbs/A | 0-45-0 Amount lbs | K2O Rate lbs/A | 0-0-60 Rate lbs/A | 0-0-60 Amount lbs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 200 | 444 | 0.43 | 100 | 167 | 0.16 |
| 2 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 100 | 222 | 0.22 | 100 | 167 | 0.16 |
| 3 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 50 | 111 | 0.11 | 100 | 167 | 0.16 |
| 4 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 400 | 889 | 0.86 | 100 | 167 | 0.16 |
| 5 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 50 | 111 | 0.11 | 100 | 167 | 0.16 |
| 6 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 200 | 444 | 0.43 | 100 | 167 | 0.16 |
| 7 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 400 | 889 | 0.86 | 100 | 167 | 0.16 |
| 8 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 100 | 222 | 0.22 | 100 | 167 | 0.16 |
| 9 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 400 | 889 | 0.86 | 100 | 167 | 0.16 |
| 10 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 50 | 111 | 0.11 | 100 | 167 | 0.16 |
| 11 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 100 | 222 | 0.22 | 100 | 167 | 0.16 |
| 12 | 6.5 | 6.5 | 42 | 0.00097 | 100 | 217 | 0.21 | 200 | 444 | 0.43 | 100 | 167 | 0.16 |
| Total | | | 507 | 0.01164 | | | 2.53 | | | 4.85 | | | 1.94 |

1993 New World Project Reclamation Plots
Fertilizer Treatments for 1994

| Location | Width ft | Length ft | Area sq ft | Area acres | N Rate lbs/A | P2O5 Rate lbs/A | K2O Rate lbs/A | 31-4-4 Rate lbs/A | 31-4-4 Amount lbs |
|---|---|---|---|---|---|---|---|---|---|
| McLaren Mine | | | | | | | | | |
| Spring seeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Spring seeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Spring unseeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Spring unseeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall seeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall seeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall unseeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall unseeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Single species | 13 | 78 | 1014 | 0.02328 | 100 | 13 | 13 | 323 | 7.52 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 100 | 13 | 13 | 323 | 3.99 |
| P rates | 19.5 | 26 | 507 | 0.01164 | 100 | 13 | 13 | 323 | 3.76 |
| OM rates | 13 | 13 | 169 | 0.00388 | 100 | 13 | 13 | 323 | 1.25 |
| Lime study | 58.5 | 80 | 4680 | 0.10744 | 100 | 13 | 13 | 323 | 34.70 |
| Total | | | 15238 | 0.34982 | | | | | 112.99 |
| Glengarry Mine | | | | | | | | | |
| Spring seeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Spring seeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall seeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall seeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall unseeded - OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Fall unseeded + OM | 39 | 26.7 | 1041 | 0.02390 | 100 | 13 | 13 | 323 | 7.72 |
| Single species | 13 | 78 | 1014 | 0.02328 | 100 | 13 | 13 | 323 | 7.52 |
| Transplants | 16.4 | 32.8 | 538 | 0.01235 | 100 | 13 | 13 | 323 | 3.99 |
| Total | | | 7800 | 0.17906 | | | | | 57.84 |
| Fisher Mountain Road | | | | | | | | | |
| Seeded | 39 | 26 | 1014 | 0.02328 | 100 | 13 | 13 | 323 | 7.52 |
| Unseeded | 39 | 26 | 1014 | 0.02328 | 100 | 13 | 13 | 323 | 7.52 |
| Total | | | 2028 | 0.04656 | | | | | 15.04 |
| Total | | | 25066 | 0.57544 | | | | | 185.87 |

# SEEDING RATES BY SPECIES IN MIXTURES: 1993 NEW WORLD PLOTS

New World Mining District Reclamation Research

| SPECIES | NO. PLS SEEDS/SQ FT | PERCENT GERM. | NO. BULK SEEDS/SQ FT | NO. BULK SEEDS/AC | NO. BULK SEEDS/LB. | NO. LBS BULK SEEDS/AC NEEDE |
|---|---|---|---|---|---|---|
| Agropyron trachycaulum | 60 | 0.80 | 75 | 3267000 | 177533 | 18.402 |
| Deschampsia caespitosa | 60 | 0.80 | 75 | 3267000 | 1513240 | 2.159 |
| Phleum alpinum | 60 | 0.80 | 75 | 3267000 | 1039690 | 3.142 |
| Poa alpina | 60 | 0.80 | 75 | 3267000 | 1428431 | 2.287 |
| Trisetum spicatum | 60 | 0.80 | 75 | 3267000 | 2118138 | 1.542 |
| Totals | 300 | | 375 | 16335000 | | 27.533 |

SEEDING RATES BY SPECIES BY PLOT: 1993 McLAREN PLOTS

| Site Number | Site Location | Number of plots | Plot size ft | Acres per plot | Acres Total | Species (grams seed required) | | | | | Total g per plot | Total g needed | Total lbs needed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Agtr | Deca | Phal | Poal | Trsp | | | |
| 1 | Daisy Pass | | | | | | | | | | | | |
| | 12-plot fall | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| 2 | McLaren Pit | | | | | | | | | | | | |
| | 12-plot spring | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| | 12-plot fall | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| | deep lime | 1 | 19.5*80 | 0.03581 | 0.03581 | 298.93 | 35.07 | 51.04 | 37.15 | 25.05 | 447.24 | 447.24 | 0.98599 |
| | shallow lime | 1 | 19.5*80 | 0.03581 | 0.03581 | 298.93 | 35.07 | 51.04 | 37.15 | 25.05 | 447.24 | 447.24 | 0.98599 |
| | no lime | 1 | 19.5*80 | 0.03581 | 0.03581 | 298.93 | 35.07 | 51.04 | 37.15 | 25.05 | 447.24 | 447.24 | 0.98599 |
| | single species | 5 | 13*13 | 0.00388 | 0.01940 | 32.38 | 3.80 | 5.53 | 4.02 | 2.71 | 48.45 | 242.25 | 0.53408 |
| | P-rates | 1 | 18*24 | 0.00992 | 0.00992 | 82.78 | 9.71 | 14.13 | 10.29 | 6.94 | 123.85 | 123.85 | 0.27304 |
| 3 | Below 72-plots | | | | | | | | | | | | |
| | 12-plot | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| 4 | Above Demo | 1 | 100*300 | 0.68871 | 0.68871 | 5748.80 | 674.45 | 981.53 | 714.44 | 481.71 | 8600.72 | 8600.72 | 18.96143 |
| 5 | Upper Fisher Road | 12 | 6.5*30 | 0.00448 | 0.05372 | 37.37 | 4.38 | 6.38 | 4.64 | 3.13 | 55.90 | 670.88 | 1.47899 |
| 6 | Glengary Adit | | | | | | | | | | | | |
| | 12-plot sping | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| | 12-plot fall | 12 | 6.5*80 | 0.01191 | 0.14296 | 99.44 | 11.67 | 16.98 | 12.36 | 8.33 | 148.77 | 1785.26 | 3.93585 |
| | single species | 5 | 13*13 | 0.00388 | 0.01940 | 32.38 | 3.80 | 5.53 | 4.02 | 2.71 | 48.45 | 242.25 | 0.53408 |
| TOTALS | | 99 | | 0.88977 | 1.75631 | 7426.91 | 871.36 | 1268.09 | 923.02 | 622.34 | 11111.71 | 21933.20 | 48.35469 |
| | | | | | 48.36 | | | | | | | | |

## SEEDING PACKETS FOR 12-PLOT SETS, P-PLOTS, AND LIME PLOTS: FALL ONLY

| SPECIES | NO. SEED PER LB | NO. SEEDS PER G | NO. VIABLE SEEDS/SQ REQUIRED | SEED VIABILITY | NO. BULK SEEDS/SQ F REQUIRED | 12-PLOT 6.5*80 | | 12-PLOT 6.5*26 | | P-PLOTS; TOTAL | | LIME RATE PLOTS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | SQ. FT. | G SEED | SQ. FT. | G SEED | SQ. FT. | G SEED | SQ. FT. | G SEED |
| AGTR | 177533 | 391 | 60 | 0.8 | 75 | 520 | 99.64 | 169 | 32.38 | 507 | 97.15 | 1560 | 298.93 |
| DECA | 1513240 | 3336 | 60 | 0.8 | 75 | 520 | 11.69 | 169 | 3.80 | 507 | 11.40 | 1560 | 35.07 |
| PHAL | 1039690 | 2292 | 60 | 0.8 | 75 | 520 | 17.01 | 169 | 5.53 | 507 | 16.59 | 1560 | 51.04 |
| POAL | 1428431 | 3149 | 60 | 0.8 | 75 | 520 | 12.38 | 169 | 4.02 | 507 | 12.07 | 1560 | 37.15 |
| TRSP | 2118138 | 4670 | 60 | 0.8 | 75 | 520 | 8.35 | 169 | 2.71 | 507 | 8.14 | 1560 | 25.06 |
| PERU CK | 1513240 | 3336 | 60 | 0.8 | 75 | 520 | 11.69 | 169 | 3.80 | 507 | 11.40 | 1560 | 35.07 |
| TOTALS | | | | | | | 149.08 | | 48.45 | | 145.36 | | 447.25 |
| NO. PACKETS NEEDED | | | | | | | 18 | | 6 | | 1 | | 3 |
| SITES | | | | | | GLENGARY ADIT<br>MCLAREN FALL<br>DAISY PASS | | UPPER FISHER CK | | MCLAREN | | MCLAREN | |

APPENDIX 3:

# LIMING RATES AND CHEMICAL PROPERTIES OF NEW WORLD DISTRICT SPOIL MATERIALS

<u>Tables</u> <u>Page</u>

Lime Requirement for McLaren-Glengarry Minespoils and Soils
1 day equilibration

| Sample | Date | T/A $CaCO_3$ | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| | | pH | | | | | | | | | | | | | | | | | |
| MM Upper Fisher Mtn. Road - East | 9/92 | 4.9 | 5.1 | 5.3 | 5.5 | | | | | | | | | | | | | | |
| MM Upper Fisher Mtn. Road - Middle | 9/92 | 4.9 | 5.2 | 5.4 | 5.7 | | | | | | | | | | | | | | |
| MM Upper Fisher Mtn. Road - West | 9/92 | 4.8 | 5.0 | 5.2 | 5.4 | | | | | | | | | | | | | | |
| MM above Demo Plots - Upper strip composite | 9/92 | 5.0 | 5.6 | 6.0 | 6.2 | | | | | | | | | | | | | | |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 5.1 | 5.3 | 5.5 | 5.8 | | | | | | | | | | | | | | |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 5.2 | 5.3 | 5.4 | 5.5 | | | | | | | | | | | | | | |
| MM below 72 Plots - Top | 9/92 | 5.2 | 5.4 | 6.0 | 6.2 | | | | | | | | | | | | | | |
| MM below 72 Plots - Middle | 9/92 | 5.0 | 5.5 | 6.0 | 6.2 | | | | | | | | | | | | | | |
| MM below 72 Plots - Bottom | 9/92 | 3.2 | | | | | | | | | | | | | | | | | |
| GM adit spoil - East | 9/92 | 2.5 | | | | 2.8 | 3.0 | 3.3 | 3.8 | 4.9 | 4.7 | 5.0 | 5.3 | 5.5 | 6.0 | 6.5 | 6.7 | | |
| GM adit spoil - Middle | 9/92 | 3.2 | | | | 4.4 | 4.8 | 5.7 | 6.2 | | | | | | | | | | |
| GM adit spoil - West | 9/92 | 3.3 | | | | 4.6 | 5.1 | 6.0 | 6.5 | | | | | | | | | | |
| MM main pit 1 | 10/92 | 3.0 | | | | 3.8 | 4.3 | 4.4 | 4.8 | 5.5 | 5.9 | 6.3 | | | | | | | |
| MM manl pit 2 | 10/92 | 3.2 | | | | 3.9 | 4.1 | 4.4 | 4.8 | 5.3 | 5.6 | 6.0 | | | | | | | |
| MM main pit 3 | 10/92 | 3.7 | | | | 4.4 | 4.7 | 5.4 | 5.9 | | | | | | | | | | |
| MM main pit 4 | 10/92 | 2.9 | | | | 3.7 | 4.0 | 4.2 | 4.6 | 5.0 | 5.9 | 5.9 | | | | | | | |
| MM main pit 5 | 10/92 | 3.2 | | | | 4.0 | 4.3 | 4.6 | 5.0 | 5.7 | 6.0 | | | | | | | | |
| MM main pit 6 | 10/92 | 2.4 | | | | 3.1 | 3.3 | 3.6 | 3.9 | 4.0 | 4.5 | 4.7 | 5.3 | 5.5 | 6.3 | | | | |
| MM main pit 7 | 10/92 | 2.6 | | | | 2.9 | 3.0 | 3.2 | 3.3 | 3.5 | 3.7 | 3.8 | 3.9 | 4.0 | 4.2 | 4.5 | 4.8 | 5.0 | 5.2 |
| MM main pit 8 | 10/92 | 5.2 | 5.8 | 6.0 | 6.3 | | | | | | | | | | | | | | |
| MM main pit 9 | 10/92 | 4.2 | | 5.0 | 5.5 | 5.7 | | | | | | | | | | | | | |

Lime Requirement for McLaren-Glengarry Minespoils and Soils
1 week equilibration

| Sample | Date | 0 | 1 | 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | T/A $CaCO_3$ | | | | | | | | | |
| | | | | | | | | | | pH | | | | | | | | | |
| MM Upper Fisher Mtn. Road - East | 9/92 | 4.9 | 5.1 | 5.2 | 5.5 | | | | | | | | | | | | | | |
| MM Upper Fisher Mtn. Road - Middle | 9/92 | 4.9 | 5.2 | 5.3 | 5.6 | | | | | | | | | | | | | | |
| MM Upper Fisher Mtn. Road - West | 9/92 | 4.8 | 5.0 | 5.1 | 5.4 | | | | | | | | | | | | | | |
| MM above Demo Plots - Upper strip composite | 9/92 | 5.0 | 5.6 | 6.0 | 6.3 | | | | | | | | | | | | | | |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 5.1 | 5.3 | 5.5 | 5.7 | | | | | | | | | | | | | | |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 5.2 | 5.3 | 5.4 | 5.5 | | | | | | | | | | | | | | |
| MM below 72 Plots - Top | 9/92 | 5.2 | 5.4 | 6.0 | 6.2 | | | | | | | | | | | | | | |
| MM below 72 Plots - Middle | 9/92 | 5.0 | 5.5 | 5.9 | 6.2 | | | | | | | | | | | | | | |
| MM below 72 Plots - Bottom | 9/92 | 3.2 | | | | | | | | | | | | | | | | | |
| GM adit spoil - East | 9/92 | 2.5 | | | | 2.8 | 2.9 | 3.1 | 3.6 | 4.4 | 4.3 | 4.5 | 4.6 | 4.9 | 5.3 | 5.9 | 6.1 | | |
| GM adit spoil - Middle | 9/92 | 3.2 | | | | 4.2 | 4.5 | 5.0 | 6.0 | | | | | | | | | | |
| GM adit spoil - West | 9/92 | 3.3 | | | | 4.5 | 4.9 | 5.7 | 6.5 | | | | | | | | | | |
| MM main pit 1 | 10/92 | 3.0 | | | | 3.7 | 4.1 | 4.2 | 4.5 | 5.2 | 5.5 | 6.2 | | | | | | | |
| MM manl pit 2 | 10/92 | 3.2 | | | | 3.8 | 4.0 | 4.3 | 4.6 | 5.2 | 5.4 | 5.9 | | | | | | | |
| MM main pit 3 | 10/92 | 3.7 | | | | 4.3 | 4.6 | 5.2 | 5.8 | | | | | | | | | | |
| MM main pit 4 | 10/92 | 2.9 | | | | 3.6 | 3.9 | 4.0 | 4.3 | 4.7 | 5.5 | 5.5 | | | | | | | |
| MM main pit 5 | 10/92 | 3.2 | | | | 3.9 | 4.1 | 4.4 | 4.7 | 5.5 | 5.7 | | | | | | | | |
| MM main pit 6 | 10/92 | 2.4 | | | | 3.0 | 3.3 | 3.5 | 3.7 | 3.9 | 4.3 | 4.4 | 5.0 | 5.2 | 5.9 | | | | |
| MM main pit 7 | 10/92 | 2.6 | | | | 2.8 | 3.0 | 3.1 | 3.2 | 3.3 | 3.5 | 3.7 | 3.8 | 3.9 | 4.1 | 4.3 | 4.6 | 4.8 | 5.2 |
| MM main pit 8 | 10/92 | 5.2 | 5.8 | 6.0 | 6.3 | | | | | | | | | | | | | | |
| MM main pit 9 | 10/92 | 4.2 | | 4.7 | 5.5 | 5.7 | | | | | | | | | | | | | |

Exchangeable Cations in McLaren-Glengarry Minespoils and Soils
2.5 g soil / 25 mL 0.1 M $NH_4Cl$ - 0.1 M $BaCl_2$, shake 30 min

| Sample | Date | Na mg/kg | K mg/kg | Mg mg/kg | Ca mg/kg | Sr mg/kg | Al mg/kg | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MM Upper Fisher Mtn Road - East | 9/92 | 3 | 50 | 99 | 363 | 9 | 231 | 6 | 1 | 8 | 1 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 2 | 80 | 81 | 347 | 8 | 239 | 9 | 2 | 2 | 1 |
| MM Upper Fisher Mtn Road - West | 9/92 | 7 | 70 | 42 | 200 | 7 | 343 | 7 | 2 | 3 | 1 |
| MM above Demo Plots - Upper strip composite | 9/92 | 3 | 70 | 39 | 477 | 8 | 146 | 8 | 2 | 0 | 0 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 4 | 80 | 45 | 233 | 8 | 222 | 10 | 2 | 0 | 0 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 4 | 30 | 107 | 477 | 9 | 454 | 2 | 0 | 0 | 0 |
| MM Below 72 Plots - Top | 9/92 | 1 | 20 | 13 | 378 | 7 | 47 | 6 | 1 | 2 | 0 |
| MM Below 72 Plots - Middle | 9/92 | 1 | 10 | 19 | 242 | 7 | 10 | 2 | 0 | 0 | 0 |
| MM Below 72 Plots - Bottom | 9/92 | 3 | 20 | 24 | 58 | 6 | 419 | 8 | 18 | 36 | 2 |
| GM adit spoil - East | 9/92 | 5 | 10 | 118 | 3712 | 7 | 230 | 15 | 1052 | 19 | 1 |
| GM adit spoil - Middle | 9/92 | 4 | 30 | 157 | 730 | 6 | 277 | 41 | 32 | 34 | 3 |
| GM adit spoil - West | 9/92 | 4 | 40 | 10 | 45 | 6 | 409 | 9 | 9 | 10 | 1 |
| MM main pit 1 | 10/92 | 5 | 20 | 98 | 748 | 7 | 407 | 38 | 115 | 48 | 4 |
| MM main pit 2 | 10/92 | 4 | 20 | 51 | 94 | 6 | 535 | 78 | 37 | 34 | 2 |
| MM main pit 3 | 10/92 | 6 | 30 | 91 | 353 | 7 | 438 | 133 | 5 | 75 | 8 |
| MM main pit 4 | 10/92 | 4 | 20 | 119 | 289 | 6 | 495 | 78 | 70 | 49 | 3 |
| MM main pit 5 | 10/92 | 6 | 30 | 65 | 179 | 6 | 460 | 66 | 48 | 26 | 2 |
| MM main pit 6 | 10/92 | 6 | 20 | 154 | 174 | 6 | 397 | 45 | 363 | 36 | 3 |
| MM main pit 7 | 10/92 | 1 | 10 | 622 | 697 | 6 | 874 | 24 | 1121 | 279 | 12 |
| MM main pit 8 | 10/92 | 4 | 40 | 170 | 1120 | 9 | 43 | 9 | 0 | 8 | 1 |
| MM main pit 9 | 10/92 | 4 | 30 | 172 | 2018 | 8 | 169 | 34 | 10 | 99 | 7 |

Exchangeable Cations in McLaren-Glengarry Minespoils and Soils
2.5 g soil / 25 mL 0.1 M $NH_4Cl$ - 0.1 M $BaCl_2$, shake 30 min

| Sample | Date | Na cmol/kg | K cmol/kg | Mg cmol/kg | Ca cmol/kg | Sr cmol/kg | Al cmol/kg | Mn cmol/kg | Fe cmol/kg | Cu cmol/kg | Zn cmol/kg | ECEC cmol/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MM Upper Fisher Mtn Road - East | 9/92 | 0.01 | 0.13 | 0.82 | 1.81 | 0.02 | 2.57 | 0.02 | 0.01 | 0.02 | 0.00 | 5.36 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 0.01 | 0.20 | 0.67 | 1.74 | 0.02 | 2.66 | 0.03 | 0.01 | 0.01 | 0.00 | 5.30 |
| MM Upper Fisher Mtn Road - West | 9/92 | 0.03 | 0.18 | 0.34 | 1.00 | 0.02 | 3.81 | 0.03 | 0.01 | 0.01 | 0.00 | 5.38 |
| MM above Demo Plots - Upper strip composite | 9/92 | 0.01 | 0.18 | 0.32 | 2.39 | 0.02 | 1.62 | 0.03 | 0.01 | 0.00 | 0.00 | 4.53 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 0.02 | 0.20 | 0.37 | 1.17 | 0.02 | 2.47 | 0.04 | 0.01 | 0.00 | 0.00 | 4.25 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 0.02 | 0.08 | 0.88 | 2.39 | 0.02 | 5.05 | 0.01 | 0.00 | 0.00 | 0.00 | 8.43 |
| MM Below 72 Plots - Top | 9/92 | 0.01 | 0.05 | 0.11 | 1.89 | 0.02 | 0.52 | 0.02 | 0.00 | 0.01 | 0.00 | 2.59 |
| MM Below 72 Plots - Middle | 9/92 | 0.00 | 0.03 | 0.16 | 1.21 | 0.02 | 0.11 | 0.01 | 0.00 | 0.00 | 0.00 | 1.53 |
| MM Below 72 Plots - Bottom | 9/92 | 0.01 | 0.05 | 0.20 | 0.29 | 0.01 | 4.65 | 0.03 | 0.10 | 0.11 | 0.01 | 5.22 |
| GM adit spoil - East | 9/92 | 0.02 | 0.03 | 0.97 | 18.56 | 0.02 | 2.56 | 0.05 | 5.66 | 0.06 | 0.00 | 22.15 |
| GM adit spoil - Middle | 9/92 | 0.02 | 0.08 | 1.30 | 3.65 | 0.01 | 3.07 | 0.15 | 0.17 | 0.11 | 0.01 | 8.13 |
| GM adit spoil - West | 9/92 | 0.02 | 0.10 | 0.08 | 0.22 | 0.01 | 4.55 | 0.03 | 0.05 | 0.03 | 0.00 | 4.98 |
| MM main pit 1 | 10/92 | 0.02 | 0.05 | 0.80 | 3.74 | 0.01 | 4.52 | 0.14 | 0.62 | 0.15 | 0.01 | 9.15 |
| MM main pit 2 | 10/92 | 0.02 | 0.05 | 0.42 | 0.47 | 0.01 | 5.95 | 0.28 | 0.20 | 0.11 | 0.01 | 6.92 |
| MM main pit 3 | 10/92 | 0.03 | 0.08 | 0.75 | 1.76 | 0.02 | 4.87 | 0.48 | 0.02 | 0.24 | 0.02 | 7.50 |
| MM main pit 4 | 10/92 | 0.02 | 0.05 | 0.98 | 1.45 | 0.01 | 5.50 | 0.28 | 0.38 | 0.15 | 0.01 | 8.01 |
| MM main pit 5 | 10/92 | 0.02 | 0.08 | 0.53 | 0.89 | 0.01 | 5.11 | 0.24 | 0.26 | 0.08 | 0.01 | 6.66 |
| MM main pit 6 | 10/92 | 0.02 | 0.05 | 1.27 | 0.87 | 0.01 | 4.41 | 0.16 | 1.95 | 0.11 | 0.01 | 6.64 |
| MM main pit 7 | 10/92 | 0.01 | 0.03 | 5.14 | 3.48 | 0.01 | 9.72 | 0.09 | 6.03 | 0.88 | 0.04 | 18.38 |
| MM main pit 8 | 10/92 | 0.02 | 0.10 | 1.40 | 5.60 | 0.02 | 0.48 | 0.03 | 0.00 | 0.02 | 0.00 | 7.63 |
| MM main pit 9 | 10/92 | 0.02 | 0.08 | 1.42 | 10.09 | 0.02 | 1.87 | 0.12 | 0.05 | 0.31 | 0.02 | 13.50 |

Extractable Metals, Phosphorus, and Sulfur in McLaren-Glengarry Minespoils and Soils
2.5 g soil / 25 mL 0.03 M NH4F - 0.1 M HCl, shake 30 min

| Sample | Date | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg | Pb mg/kg | Al mg/kg | P mg/kg | S mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| MM Upper Fisher Mtn Road - East | 9/92 | 44 | 1602 | 34 | 5 | 4 | 4240 | 44 | 57 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 60 | 1556 | 15 | 6 | 5 | 4142 | 61 | 27 |
| MM Upper Fisher Mtn Road - West | 9/92 | 59 | 1547 | 22 | 5 | 4 | 4712 | 45 | 32 |
| MM above Demo Plots - Upper strip composite | 9/92 | 71 | 1523 | 14 | 5 | 3 | 5326 | 33 | 120 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 88 | 1237 | 13 | 6 | 3 | 5633 | 28 | 22 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 9 | 539 | 15 | 1 | 3 | 5275 | 6 | 11 |
| MM Below 72 Plots - Top | 9/92 | 36 | 1760 | 73 | 3 | 7 | 1958 | 6 | 80 |
| MM Below 72 Plots - Middle | 9/92 | 4 | 453 | 8 | 1 | 6 | 479 | 1 | 70 |
| MM Below 72 Plots - Bottom | 9/92 | 14 | 2453 | 50 | 4 | 3 | 1256 | 16 | 508 |
| GM adit spoil - East | 9/92 | 13 | 10119 | 20 | 1 | 2 | 441 | 197 | 11403 |
| GM adit spoil - Middle | 9/92 | 71 | 2909 | 48 | 6 | 4 | 1130 | 107 | 3253 |
| GM adit spoil - West | 9/92 | 17 | 1366 | 14 | 1 | 5 | 1032 | 7 | 225 |
| MM main pit 1 | 10/92 | 66 | 3055 | 66 | 8 | 2 | 1313 | 50 | 1880 |
| MM main pit 2 | 10/92 | 132 | 3861 | 53 | 9 | 11 | 2193 | 47 | 942 |
| MM main pit 3 | 10/92 | 191 | 2797 | 102 | 15 | 17 | 2282 | 72 | 1534 |
| MM main pit 4 | 10/92 | 113 | 2637 | 55 | 6 | 3 | 1383 | 34 | 1241 |
| MM main pit 5 | 10/92 | 119 | 4014 | 38 | 7 | 5 | 1888 | 39 | 827 |
| MM main pit 6 | 10/92 | 65 | 4448 | 38 | 6 | 2 | 1020 | 44 | 1655 |
| MM main pit 7 | 10/92 | 33 | 6576 | 298 | 16 | 2 | 2290 | 224 | 5541 |
| MM main pit 8 | 10/92 | 71 | 587 | 219 | 19 | 25 | 6195 | 16 | 446 |
| MM main pit 9 | 10/92 | 57 | 2585 | 229 | 16 | 3 | 1411 | 56 | 2596 |

Extractable Metals, Phosphorus, and Sulfur in McLaren-Glengarry Minespoils and Soils
2.5 g soil / 25 mL 0.1 M HCl, shake 30 min

| Sample | Date | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg | Pb mg/kg | Al mg/kg | P mg/kg | S mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| MM Upper Fisher Mtn Road - East | 9/92 | 11 | 82 | 24 | 1 | 1 | 618 | 10 | 8 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 17 | 100 | 9 | 1 | 2 | 670 | 21 | 3 |
| MM Upper Fisher Mtn Road - West | 9/92 | 13 | 87 | 16 | 1 | 2 | 1080 | 13 | 5 |
| MM above Demo Plots - Upper strip composite | 9/92 | 18 | 101 | 8 | 1 | 1 | 1511 | 12 | 26 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 18 | 67 | 7 | 1 | 1 | 1537 | 7 | 1 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 2 | 27 | 3 | 0 | 1 | 931 | 0 | 0 |
| MM Below 72 Plots - Top | 9/92 | 16 | 75 | 35 | 1 | 5 | 327 | 0 | 5 |
| MM Below 72 Plots - Middle | 9/92 | 2 | 8 | 4 | 0 | 5 | 26 | 0 | 3 |
| MM Below 72 Plots - Bottom | 9/92 | 9 | 222 | 43 | 2 | 1 | 266 | 3 | 114 |
| GM adit spoil - East | 9/92 | 15 | 4626 | 21 | 1 | 1 | 285 | 222 | 11739 |
| GM adit spoil - Middle | 9/92 | 59 | 589 | 41 | 3 | 2 | 375 | 171 | 2808 |
| GM adit spoil - West | 9/92 | 11 | 114 | 13 | 2 | 2 | 259 | 2 | 52 |
| MM main pit 1 | 10/92 | 53 | 730 | 60 | 5 | 1 | 432 | 35 | 1508 |
| MM main pit 2 | 10/92 | 115 | 591 | 43 | 3 | 6 | 609 | 23 | 439 |
| MM main pit 3 | 10/92 | 175 | 330 | 90 | 10 | 11 | 535 | 42 | 978 |
| MM main pit 4 | 10/92 | 97 | 531 | 54 | 4 | 1 | 416 | 18 | 778 |
| MM main pit 5 | 10/92 | 91 | 545 | 28 | 2 | 3 | 433 | 12 | 278 |
| MM main pit 6 | 10/92 | 58 | 1301 | 37 | 3 | 1 | 336 | 26 | 1088 |
| MM main pit 7 | 10/92 | 30 | 3632 | 303 | 14 | 2 | 998 | 234 | 5615 |
| MM main pit 8 | 10/92 | 37 | 76 | 154 | 7 | 26 | 2015 | 9 | 248 |
| MM main pit 9 | 10/92 | 51 | 604 | 191 | 10 | 1 | 335 | 40 | 1988 |

Extractable Metals, Phosphorus, and Sulfur in McLaren-Glengarry Minespoils and Soils
0.5 g soil / 25 mL 0.1 M NaOH - 0.1 M NaCl, shake 24 h

| Sample | Date | Al mg/kg | P mg/kg | As mg/kg | S mg/kg |
|---|---|---|---|---|---|
| MM Upper Fisher Mtn Road - East | 9/92 | 4614 | 575 | 40 | 2505 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 4485 | 680 | 35 | 2490 |
| MM Upper Fisher Mtn Road - West | 9/92 | 5749 | 710 | 55 | 2825 |
| MM above Demo Plots - Upper strip composite | 9/92 | 6546 | 625 | 50 | 2815 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 5276 | 500 | 35 | 1070 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 5288 | 300 | 35 | 1960 |
| MM Below 72 Plots - Top | 9/92 | 1630 | 245 | 20 | 1895 |
| MM Below 72 Plots - Middle | 9/92 | 424 | 105 | 0 | 1465 |
| MM Below 72 Plots - Bottom | 9/92 | 800 | 435 | 30 | 4635 |
| GM adit spoil - East | 9/92 | 20 | 400 | 10 | 23490 |
| GM adit spoil - Middle | 9/92 | 341 | 155 | 10 | 7830 |
| GM adit spoil - West | 9/92 | 507 | 260 | 25 | 5165 |
| MM main pit 1 | 10/92 | 655 | 415 | 15 | 7100 |
| MM main pit 2 | 10/92 | 1523 | 425 | 15 | 3970 |
| MM main pit 3 | 10/92 | 1625 | 435 | 20 | 4210 |
| MM main pit 4 | 10/92 | 698 | 485 | 10 | 8650 |
| MM main pit 5 | 10/92 | 1162 | 510 | 15 | 5375 |
| MM main pit 6 | 10/92 | 523 | 630 | 5 | 9145 |
| MM main pit 7 | 10/92 | 965 | 805 | 10 | 19980 |
| MM main pit 8 | 10/92 | 6936 | 345 | 45 | 2400 |
| MM main pit 9 | 10/92 | 452 | 430 | 10 | 11850 |

Sequential Extraction of McLaren - Glengarry Minespoils and Soils

| Sample | Date | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg | Pb mg/kg | Al mg/kg | P mg/kg | S mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| Amorphous Fe Oxides: 0.25 M NH2OH HCl - 0.25 M HCl (1:50) | | | | | | | | | |
| MM Upper Fisher Mtn Road - East | 9/92 | 122 | 6816 | 158 | 7 | 15 | 3489 | 250 | 325 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 133 | 5320 | 49 | 7 | 20 | 3119 | 235 | 95 |
| MM Upper Fisher Mtn Road - West | 9/92 | 177 | 7072 | 48 | 8 | 20 | 3955 | 275 | 160 |
| MM above Demo Plots - Upper strip composite | 9/92 | 222 | 6947 | 30 | 8 | 20 | 4861 | 235 | 250 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 322 | 6017 | 29 | 9 | 15 | 5245 | 215 | 60 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 30 | 2695 | 31 | 2 | 10 | 3741 | 20 | 55 |
| MM Below 72 Plots - Top | 9/92 | 473 | 7125 | 210 | 7 | 25 | 1829 | 25 | 330 |
| MM Below 72 Plots - Middle | 9/92 | 15 | 1320 | 28 | 2 | 15 | 270 | 0 | 140 |
| MM Below 72 Plots - Bottom | 9/92 | 59 | 9782 | 113 | 6 | 25 | 1054 | 75 | 1300 |
| GM adit spoil - East | 9/92 | 14 | 37027 | 51 | 2 | 10 | 689 | 990 | 38160 |
| GM adit spoil - Middle | 9/92 | 141 | 10214 | 91 | 9 | 25 | 1082 | 390 | 4360 |
| GM adit spoil - West | 9/92 | 53 | 3874 | 28 | 1 | 25 | 851 | 40 | 475 |
| MM main pit 1 | 10/92 | 109 | 16061 | 136 | 14 | 55 | 1349 | 210 | 2915 |
| MM main pit 2 | 10/92 | 794 | 18021 | 127 | 21 | 85 | 2215 | 235 | 1800 |
| MM main pit 3 | 10/92 | 628 | 10867 | 190 | 27 | 110 | 2281 | 250 | 1665 |
| MM main pit 4 | 10/92 | 198 | 18878 | 156 | 13 | 85 | 1480 | 165 | 3070 |
| MM main pit 5 | 10/92 | 468 | 16770 | 89 | 13 | 80 | 1805 | 200 | 1650 |
| MM main pit 6 | 10/92 | 195 | 23381 | 97 | 14 | 90 | 1046 | 235 | 3375 |
| MM main pit 7 | 10/92 | 43 | 26494 | 542 | 26 | 125 | 3013 | 835 | 8050 |
| MM main pit 8 | 10/92 | 355 | 4503 | 385 | 47 | 80 | 5882 | 40 | 545 |
| MM main pit 9 | 10/92 | 80 | 18551 | 481 | 26 | 110 | 1389 | 225 | 4260 |
| Crystalline Fe Oxides: 0.2 M NH4Ox - 0.2 M HOx - 0.1 M ascorbic acid (1:100) | | | | | | | | | |
| MM Upper Fisher Mtn Road - East | 9/92 | 23 | 25748 | 84 | 4 | 30 | 3628 | 910 | 1390 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 38 | 26205 | 89 | 19 | 30 | 3482 | 890 | 1200 |
| MM Upper Fisher Mtn Road - West | 9/92 | 34 | 24951 | 71 | 24 | 30 | 3942 | 850 | 1460 |
| MM above Demo Plots - Upper strip composite | 9/92 | 39 | 23353 | 71 | 21 | 30 | 4336 | 780 | 1470 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 41 | 27089 | 74 | 20 | 30 | 4896 | 700 | 850 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 2 | 32760 | 127 | 0 | 30 | 4948 | 900 | 910 |
| MM Below 72 Plots - Top | 9/92 | 0 | 68717 | 216 | 0 | 30 | 2526 | 490 | 1000 |
| MM Below 72 Plots - Middle | 9/92 | 0 | 100600 | 233 | 0 | 30 | 1687 | 270 | 1000 |
| MM Below 72 Plots - Bottom | 9/92 | 1 | 57732 | 202 | 0 | 60 | 1480 | 560 | 2280 |
| GM adit spoil - East | 9/92 | 3 | 13979 | 0 | 0 | 10 | 853 | 180 | 3300 |
| GM adit spoil - Middle | 9/92 | 2 | 26931 | 22 | 0 | 40 | 1252 | 390 | 4030 |
| GM adit spoil - West | 9/92 | 0 | 30428 | 66 | 0 | 40 | 764 | 350 | 3620 |
| MM main pit 1 | 10/92 | 15 | 38339 | 59 | 0 | 180 | 1767 | 670 | 2950 |
| MM main pit 2 | 10/92 | 61 | 40760 | 106 | 3 | 140 | 2407 | 710 | 1890 |
| MM main pit 3 | 10/92 | 25 | 35500 | 142 | 4 | 160 | 2105 | 750 | 1570 |
| MM main pit 4 | 10/92 | 17 | 41583 | 56 | 0 | 210 | 1850 | 680 | 3160 |
| MM main pit 5 | 10/92 | 41 | 36914 | 107 | 1 | 160 | 2091 | 730 | 1970 |
| MM main pit 6 | 10/92 | 8 | 41835 | 198 | 5 | 400 | 1664 | 820 | 3230 |
| MM main pit 7 | 10/92 | 4 | 29099 | 60 | 1 | 450 | 1666 | 680 | 5180 |
| MM main pit 8 | 10/92 | 23 | 46485 | 380 | 8 | 100 | 5011 | 690 | 880 |
| MM main pit 9 | 10/92 | 6 | 41767 | 56 | 1 | 360 | 1985 | 710 | 4340 |

Sequential Extraction of McLaren - Glengarry Minespoils and Soils

| Sample | Date | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg | Pb mg/kg | Al mg/kg | P mg/kg | S mg/kg |
|---|---|---|---|---|---|---|---|---|---|
| Organic matter + Sulfides + Residual: conc. HNO3 - conc. HCl - 30 % H2O2 (1:100) | | | | | | | | | |
| MM Upper Fisher Mtn Road - East | 9/92 | 101 | 21917 | 122 | 56 | 10 | 12415 | 0 | 2690 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 95 | 15889 | 52 | 36 | 10 | 11792 | 0 | 120 |
| MM Upper Fisher Mtn Road - West | 9/92 | 95 | 14229 | 60 | 34 | 10 | 12050 | 0 | 370 |
| MM above Demo Plots - Upper strip composite | 9/92 | 72 | 15225 | 62 | 38 | 10 | 11851 | 0 | 1070 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 67 | 14101 | 41 | 29 | 10 | 10316 | 0 | 130 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 40 | 21062 | 87 | 23 | 10 | 9646 | 0 | 220 |
| MM Below 72 Plots - Top | 9/92 | 51 | 137220 | 495 | 47 | 40 | 4385 | 0 | 1560 |
| MM Below 72 Plots - Middle | 9/92 | 40 | 140180 | 594 | 45 | 40 | 1976 | 0 | 580 |
| MM Below 72 Plots - Bottom | 9/92 | 114 | 94586 | 332 | 41 | 30 | 2682 | 0 | 1170 |
| GM adit spoil - East | 9/92 | 9 | 25067 | 294 | 2 | 0 | 3471 | 0 | 23630 |
| GM adit spoil - Middle | 9/92 | 20 | 16953 | 141 | 8 | 0 | 3675 | 0 | 6900 |
| GM adit spoil - West | 9/92 | 4 | 10142 | 24 | 3 | 10 | 1877 | 0 | 160 |
| MM main pit 1 | 10/92 | 135 | 35387 | 421 | 255 | 30 | 5127 | 0 | 18310 |
| MM main pit 2 | 10/92 | 283 | 24310 | 330 | 77 | 30 | 7166 | 0 | 5070 |
| MM main pit 3 | 10/92 | 179 | 15754 | 109 | 56 | 20 | 5365 | 0 | 1850 |
| MM main pit 4 | 10/92 | 137 | 21676 | 399 | 60 | 40 | 5184 | 0 | 4640 |
| MM main pit 5 | 10/92 | 215 | 17823 | 163 | 54 | 50 | 5978 | 0 | 2430 |
| MM main pit 6 | 10/92 | 127 | 15265 | 99 | 52 | 40 | 4244 | 0 | 980 |
| MM main pit 7 | 10/92 | 48 | 56592 | 1751 | 128 | 100 | 4073 | 0 | 50960 |
| MM main pit 8 | 10/92 | 81 | 30490 | 174 | 113 | 20 | 5850 | 0 | 530 |
| MM main pit 9 | 10/92 | 90 | 45732 | 606 | 80 | 70 | 5246 | 0 | 33000 |
| Sum of Sequential Extractions | | | | | | | | | |
| MM Upper Fisher Mtn Road - East | 9/92 | 246 | 55481 | 364 | 67 | 55 | 19532 | 1160 | 4405 |
| MM Upper Fisher Mtn Road - Middle | 9/92 | 266 | 47414 | 190 | 62 | 60 | 18393 | 1125 | 1415 |
| MM Upper Fisher Mtn Road - West | 9/92 | 306 | 46252 | 179 | 66 | 60 | 19947 | 1125 | 1990 |
| MM above Demo Plots - Upper strip composite | 9/92 | 333 | 45526 | 163 | 67 | 60 | 21048 | 1015 | 2790 |
| MM above Demo Plots - Middle strip topsoil | 9/92 | 430 | 47207 | 144 | 58 | 55 | 20457 | 915 | 1040 |
| MM above Demo Plots - Middle strip subsoil | 9/92 | 72 | 56517 | 245 | 25 | 50 | 18335 | 920 | 1185 |
| MM Below 72 Plots - Top | 9/92 | 524 | 213062 | 921 | 54 | 95 | 8740 | 515 | 2890 |
| MM Below 72 Plots - Middle | 9/92 | 55 | 242100 | 855 | 47 | 85 | 3933 | 270 | 1720 |
| MM Below 72 Plots - Bottom | 9/92 | 174 | 162100 | 647 | 47 | 115 | 5216 | 635 | 4750 |
| GM adit spoil - East | 9/92 | 26 | 76073 | 345 | 4 | 20 | 5013 | 1170 | 65090 |
| GM adit spoil - Middle | 9/92 | 163 | 54098 | 254 | 17 | 65 | 6009 | 780 | 15290 |
| GM adit spoil - West | 9/92 | 57 | 44444 | 118 | 4 | 75 | 3492 | 390 | 4255 |
| MM main pit 1 | 10/92 | 260 | 89787 | 616 | 269 | 265 | 8243 | 880 | 24175 |
| MM main pit 2 | 10/92 | 1138 | 83091 | 563 | 101 | 255 | 11788 | 945 | 8760 |
| MM main pit 3 | 10/92 | 832 | 62121 | 441 | 87 | 290 | 9751 | 1000 | 5085 |
| MM main pit 4 | 10/92 | 352 | 82137 | 611 | 73 | 335 | 8514 | 845 | 10870 |
| MM main pit 5 | 10/92 | 724 | 71507 | 359 | 68 | 290 | 9874 | 930 | 6050 |
| MM main pit 6 | 10/92 | 330 | 80481 | 394 | 71 | 530 | 6954 | 1055 | 7585 |
| MM main pit 7 | 10/92 | 95 | 112185 | 2353 | 155 | 675 | 8752 | 1515 | 64190 |
| MM main pit 8 | 10/92 | 459 | 81478 | 939 | 168 | 200 | 16743 | 730 | 1955 |
| MM main pit 9 | 10/92 | 176 | 106050 | 1143 | 107 | 540 | 8620 | 935 | 41600 |